SPATIAL ANALYSIS OF CHINESE GARDEN DESIGNS WITH MACHINE LEARNING

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Abstract. This research intends to propose a scheme for analyzing Chinese Garden Design by incorporating spatial theory, data mining, concept of object, and network-like data structure. Design elements of Chinese garden are placed in a network according to the existing gardens according to spatial theory. Collected networks are then divided into pair of elements connected by their relationship and stored in a database. Later, data mining is applied to attain patterns from the node-and-relationship pairs. Meanwhile, the elements of the same level can be classified and data grouping can be done by the implementation itself.

Thru this research, we can gain insight upon the spatial information and relationship between elements of Chinese garden designs. The result is a set of more concise and structural descriptions, which reveals the rhythm behind the Chinese garden design and can be a great pedagogical aid.

1. Forward

The definition of design style has long been a popular subject open to discussion. It is agreed by most of the concerning researchers that the meaning of style is beyond each individual design elements. A style is a creation out of meaningful composition of individual design elements or the symbolism behind the design elements.

The style of traditional Chinese garden has long been recognized as a unique system in creating landscape dramatically different from western approaches. Unfortunately, due to the cultural bias and emphasize, texts or records for garden design either focus on the single design or construction elements, or describe the scheme as experience in highly abstract forms. Contemporary designers when intend to apply Chinese garden style either copy-and-paste layouts from the past or simply stack traditional elements in western schemes.

With the advancements of computing science, especially in Artificial Intelligence, more methods and tools are available to better understand behavior, concept and environment. A recently developed and flourished technique in this field, machine learning or data mining to be precise, has provided a powerful means to re-exam the data which we were previously incapable of analyzing or trashed. Data mining is about finding pattern in collected data, especially large quantity of data. It is a process to identify hidden characteristics, thus the data is presented in a more concise and structural manner. The result will be helpful in explaining the data and making predictions.

Generally, knowledge is represented as a tree or frame structure. Either structure presents a certain hierarchy of components ranked in terms of importance or bias. Due to the limitation on the representation and operations of these constructs, certain relationships are removed and can no longer be recovered in further circumstance. While working with spatial information, this fault becomes a little more obvious and intolerable. Because of the formal similarity, a network is a more natural and feasible solution for treating spatial data, since no recognizable information is removed due to the representing structure or operations.

The concept of object-oriented programming enables us to realize and present the universe with different level of details or classes. The concept of object is a best fit for describing spatial information with different levels of abstractions. And, it is also a perfect match for presenting nodes in the network, since a node may be composed with sets of complex objects.

This research intends to propose a scheme for analysing Chinese Garden Design by incorporating spatial theory, data mining, network-like data structure, and concept of object. Design elements of Chinese garden are placed in a network according to the existing traditional gardens according to spatial theory. Collected networks are then broken down into pairs of elements connected by their relationship and stored in a database. While breaking down the network will not purge the original structure and affect the integrity of information. Later, data mining is applied to attain patterns from the node-and-relationship pairs. Meanwhile, the elements of the same level can be classified and data grouping can be done by the implementation itself.

Thru this research, we can gain insight upon the spatial information and relationship between elements of Chinese garden designs. The result is a set of more concise and structural descriptions, which may provide us a peak into the rhythm behind the Chinese garden design and can be a great pedagogical aid.

2. Introduction

Combining the Confucianism, Taoism and Buddhism, Chinese garden design has long been famous for its unique characteristics deeply affected by its culture. Under the influence of tradition Chinese code of belief, educated intellectuals were more engaged in the process of mimicking and minimizing nature into confined artificial spaces – gardens rather than building itself. This nature of focus on the particular category of design truthfully reflects the recognition and philosophy to their rural surrounding.

3. Subjects of this project

On the other hand, the cultural bias toward craftsmanship also reflects on the approaches for recording and describing the garden design. Two distinct descriptions can be found for this purpose. The first category tends to focus on the construction techniques for each garden device, such as window or stone pavement. On the other hand, due to the involvement of scholars, poetic texts are the major form used to describe the environment setting. Both are awkward for today's training practice.

According to Schmitt (Schmitt1999), information can be declared as the fifth dimension of architecture. The information can be classified in four categories:

1. Information residing in the designer's memory, directly influencing the design

   This category is the most frequently discussed and recorded. During the design process, instinct, memory and design knowledge are major design resources. The content of individual memory shapes the design into a certain tendency and outcome. The similarities, whether externally visible or just internally/mentally acknowledged, are often recognized as one's design style.
2. Information from outside, formalized external references

   This category emphasizes the externally visible features of building. The visual references of motifs or design elements are powerful tools to communicate design philosophy. Impression of a building is often underlies in its formal appearance.
3. Information generated in the design and construction process itself

New ideas and insights are gaining or created while facing problem to be solved. During problem-solving stage, this type of information is generated to approach the possible solutions.

4. Information come into existence during the lifetime of the building
This type of information is generated during the post-occupancy period. The changes, such as modifications and add-ons, of the building to suit the users are important for certain design aspects. The individuality of space is created after the users move in and start using it. The condition of the building provides extremely important information for designers to observe and review the performance of their designs.

This project focuses on the second category of information. The external formation is easier to observe and access. The underlying meanings for the design elements are temporally ignored to simplify this research. This research is the first phase of a series investigation into Chinese garden design in my lab. By means of digital techniques, we intend to uncover more tangible and maybe operable clues other than abstract portrays of mental scenes.

4. Purpose of this project

Design is an ever-evolving process. When the development is longer updated, the design is doomed to be out-of-date and forgotten. Unfortunately, the evolution of contemporary Chinese garden design has been on a hold for almost a century. Frequent, the recent design is a cut-and-paste of traditional Chinese gardens. The design and presentation seems still frozen and unchanged with ancient components.

To enable the temporary designers to reflect the contemporary technology, material and artistic appreciation in the “new” Chinese garden designs, this research intend to rediscover the hidden sensation uniquely provided in the arrangement of Chinese garden. The result is digital recorded, analysed and presented to demonstrate the spatial rhythm.

5. Tools

Numerous machine-learning techniques, such as neural network, signal process and etc., fail to recognize the importance for human recognition. The classified patterns from collected data are hardly recognizable by human users. For designers, the design knowledge is, if not more important, as significant as design approach. Being able to understand and review the content of the recovered knowledge is essential for further

6. Symbols, components and expressions

Human communication is greatly limited by the language they use. Either sounds or words are basic elements putting together to form idea or significant message. To compose a meaningful sentence, certain rules are followed to make the sentence commonly understandable. Besides grammar, to express a meaningful sentence, semantics plays the major role.

If we take design as an expression of thought for communication, then the design components can be treated as words or vocabularies, arrangements resembles grammar, and design styles are individual semantics for different languages. Hence, we may describe design style in a logical and symbolic notation.

In this research, we intend to define a subset of the design vocabularies of Chinese garden design and the possible grammar and semantics for traditional Chinese garden.

7. Research process

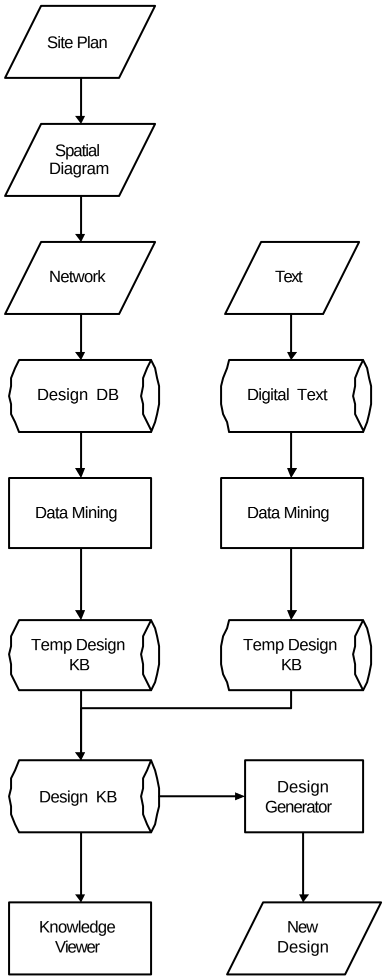

Figure 1. Process flowchart.

7.1. TEXTUAL INFORMATION

The first section of this research is to build basic dictionary for Chinese garden design and then build the primary knowledge base to record the relationship between vocabularies in the dictionary. To do this, few traditional Chinese garden design books are selected according their importance and content.

In order to process the textual data, text will first be transformed into digital format. Later, the digital text stream will be fed word by word into the data mining process as the raw data.

Textual process for Chinese language is a two-pass process. Unlike the western language such as English, the actually meaning represented is determined by the semantic in Chinese. In English, the word "Book" carried a literal meaning of the book object. However, in Chinese, the true meaning cannot determine with a single word, but depending on the words before and after it. Frequently, words do not posses any meaning until they are combined into vocabularies by the context. The meaning of a sentence is not determined until the vocabularies (usually has length of 2 to 4 words individually) have been identified. Hence, the first step of preparation for data minding is to build a basic dictionary composed of essential vocabularies.

Each paragraph of digital text will consist of sentences and punctuation marks. A period mark usually indicates end of a complete thought and comma usually allows a brief break in a thought. According to the basic grammatical convention of the punctuation mark, the digital text can be read in as segments.

Example:

"abcde,efghbci,jklmno.rsba,tuvwxyz."

The above 2 sentences can be read as 5 segements:

Segment 1 -> abcde
Segment 2 -> efghbci
Segment 3 -> jklmno
Segment 4 -> rsbc
Segment 5 -> tuvwxyz

The first vocabulary in the first segment can be composted by one or up to four words: a, ab, abc, abcd and abcde. In the first segment, there are 5+4+3+2+1 = 15 possible vocabularies. One will notice the number of permutation is the summation from 1 to number of words in the segment/sentence. If we apply the rule of thumb mentioned above and limit the vocabulary down to four words at most, we can greatly reduce the number of possible combinations. The total possible vocabularies from the first segment can be reduced from 15 to 14. The first sentence of this example will then produce 14 + 22 + 22 + 10 + 22 = 90 basic vocabularies. To process a book will produce countless possible vocabularies.

Two major approaches for building the basic dictionary are considered: fully automatic or expert assisted.

The first method relies on the power of data mining to find all possible vocabularies. The program will start from scratch with an empty dictionary.

The content of the dictionary is gradually built up while reading text. The second method relies on human expert to build the dictionary. Vocabularies are hand picked by the expert.

The automatic approach has the advantage of ease of process, however it can be time consuming and the accuracy may not be high. However, it is easier to handle the ever-increasing size of dictionary. To add new vocabulary does not require complex operation. On the other hand, if expert manually assist in building the basic dictionary by providing known vocabularies into the dictionary, the process will be more accurate, but the disadvantage will be the manual labor cost and difficult to update. Human expert must be brought in to verify the additional vocabulary is legit and not in the dictionary.

At the end of the first pass, the vocabulary-building process will have generated a basic vocabulary list from the digital text stream. Next, the relationship between the vocabularies from the same segment/sentence will be determined and a computed weight (bias) will be assigned to it.

Carry on the above example for the second pass:

"abcde,efghbci,jklmno.rsba,tuvwxyz."

Suppose that in the first sentence, there are 10 basic vocabularies identified, namely a, b, cd, ef, hb, kl, no, tu, wx, and yz. Now the relationship between the each vocabulary can be characterize as the followed:

Segment1 is consisted of "a, b, cd".

Vocabulary "a" will have a relationship to all the other vocabularies:

a – b

a – cd

For each of the above relationships, weight of "1" is assigned. The same relationship will also be established between "b" and its neighboring vocabularies in the same segment. The operation is done only once for each pair of vocabularies, therefore the relationship b – a is ignored for redundancy reason..

The comma marks the end of the first segment, but not end of the relationship for vocabulary "a", for "a" it will also have relationship with vocabulary in the second segment:

a – ef

a – hb

Since the two vocabularies are separated by a comma, this might indicate that they have a less close relationship therefore the weight assigned to the link between them shall be lower than the previous example. Hence, we assign 1/2 as their weight. The process repeats itself for the third, fourth segments and so on. The assigned weight decreases as it move on, such as 1/3, 1/4 and so on. Once the period has been reached, the process will be stop and then restart the whole process with another vocabulary again.

As one may already notice the second pass is really a relationship builder. At the end of this process, a large set of relationships with various weights for each pair of the vocabularies in the basic dictionary is established. However, the same pair of vocabularies may appear in the text more than once, but in reverse order. The same relationship may be established multiply times. The redundancy control will be enforced to address such an issue. In the example "b – a" has occurred when the relationship builder is reading the forth segment, the repeated relationship will be found and eliminated.

After the digital text stream has been fed through the vocabulary builder (first pass) and then the relationship builder (second pass), the result will now be ready for further cross examined with the result from the second part of the research.

7.2. DIAGRAM CONVERSION

The second section of this research is to generate a design knowledge base from real design cases. The content of the result is then cross-examine and later combined with the knowledge base generated in the first section.

In this experiment, we start with four garden designs, the most famous Traditional Chinese gardens in the southern China. Three of them are utilized for constructing the knowledge base and one for testing and verification.

The first step is to identify the fundamental objects to be recognized in the real design cases. In this research, to simplify the initial experiment, only significant objects are counted as of importance. In Chinese garden design, flowers are never the outstanding features – they are not even essential (Powell, 1943), and items such as decoration, opening and corridor are not recognized and ignored. After being identified, objects are represented with the vocabularies found in the last section.

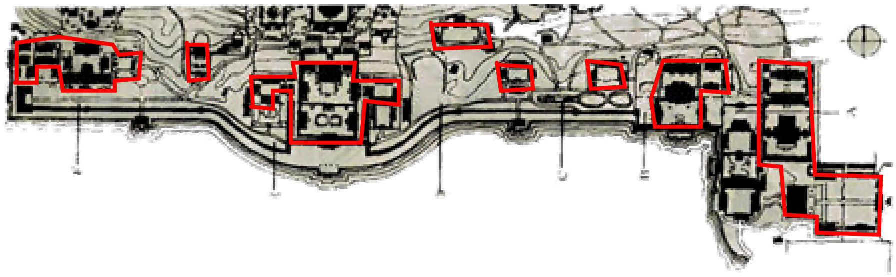

Figure 2. Site plan for conversion.

The second process starts with the site plan of those gardens. With the vocabularies from the dictionary, important objects are located, circled and labelled with corresponding vocabularies. Once insignificant objects are all isolated, and others are identified; we now have transferred a site plan into a diagram. The next step is to decide the relationships between these identified objects.

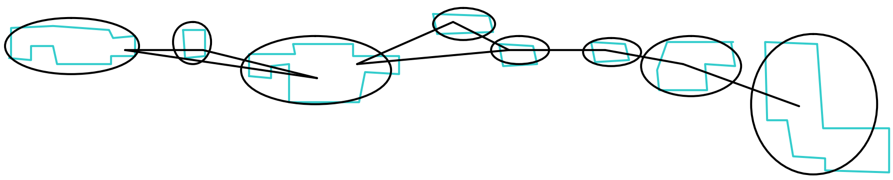

Figure 3. Converted site plan.

Distance and visibility are two criteria for determining the relationship between identified objects. Sets of range of distance are tested to decide which distance is reasonable. The second criterion is whether two objects are not visually obstructed from each other. If two objects are qualified under these two criteria, then they are recognized as spatially related and a link is established between them.

Once the network has been established, we can further classify the relationship. Although "weights" are used for computing the relationship between vocabularies in the textual process, the weights for the spatial objects are not yet determined for this experiment. Each spatial object within the network has a 1-to-1 relationship to another spatial object. The n-to-n scenario can be thought of as n*n times of the basic 1-to-1 relationships. This resulting set of relationship is then process with the data mining tools to build the knowledge base.

Combining the two temporary knowledge bases (one from the textual process and the one from the site plan process), a design knowledge base can be created. To test the accuracy and usability of the knowledge database, one remaining site plan is to be test against this knowledge base.

Expected Result and Problems

Since this is the first endeavor to analyze and combine textural and diagram information on Chinese garden design, the result is not certain at current research stage.

The foreseeable research problems are listed below:

1. Assigned weights during the first process do not reflect the relationship between vocabularies.
2. The text-feeding process does not recognize the verbs or negations, which might introduce an opposite meaning between vocabularies.
3. The conversion in the second process might over-simplify the diagram. This may result in getting a small set of information, which does not have enough material to be used for data mining.
4. The experiment size is not sufficient to generate a meaning knowledge base. This problem can be solved in the future by continuously extending the data set, while incorporating more experiment cases.
5. Visualizing the content in the knowledge base is difficult for human. Before a better way or interface between the human user and knowledge base is developed, we cannot be very certain the quality of the content.

Future development

For the future, following objective will be further explored:

1. To create a design generator that utilized the design knowledge base and help designer thru the design process.
2. To optimise the knowledge database to be more widely accessible by people who are not familiar with design pattern or process.
3. To build an information browser enabling people to better understand the content in the knowledge base.

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