MODELLING MONDRIAN'S DESIGN PROCESSES AND THEIR ARCHITECTURAL ASSOCIATIONS USING MULTILAYER NEURAL NETWORKSS

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Abstract. Can artificial intelligence be used for design behavior of human beings? Human designer's behavior and design thinking are extremely complicated. There is still argument about the relationship between the two until now. Therefore, this research only investigates regular and common design behavior. This essay is taking Mondrian of Neo-Plasticism as an example and neural networks systems as a tool to illustrate the core idea. It is hoped that we can simulate the design thinking ability, such as memory association and recognition of human designers. Computation of neural networks systems, as a result and the difference between human designers and computer, can be discussed too. Also, since the work of Neo-Plasticism Mondrian influences contemporary architecture design, industrial design, andvisual design directly or indirectly, floorplans of architect John Hejduk's works were taken as an example to discuss the application of Neural networkss in the design field.

1. Introduction

Human designer's behavior and design thinking are extremely complicated. Various computations such as symbolic and neural processes have been seriously examined in the literature of computer-aided design systems (Gero 1994; Stiny 1993; Mitchell 1993; Liu 1995). The newly developing ideas of neural networkss seems to provide some potential for memory association and shape recognition (Coyne 1992; Liu 1993, 1994, 1995). However the reasoning capacity of neural processing is still very limited because neural networkss simply provide single mapping between input and output patterns. This limitation on reasoning becomes a serious obstacle for the neural applications to computer-aided design systems. This study intends to develop a more complex reasoning capability for neural networkss to be used in design. The objective is to simulate the mapping between beginning

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sketches and the final design outcomes. In other words, this paper tends to simulate the entire design process from the early stage to the end by using multilayer neural networkss, rather than the simulation of single mapping for memory association and shape recognition.

Mondrian's geometric abstract paintings in Neo-Plasticism were taken as an example to illustrate the core idea mentioned above. It is also expected that the difference between human designers and neural networks systems can be discussed.

2. The relationship of neural networks and design behavior

Neural networkss have the capability of learning , storing , fault tolerance and categorization. These capabilities more or less involve some design process and behavior. Human beings use sensation like vision, hearing, touch, smell and taste in their design process. Their design thinking models contain creation, memorization, recall, and decision making. The whole design process is very complicated from initial to goal state. Some related problems still could not be solved by the current computer system. However, Neural networkss research could search design information (Coyne, Yokozawa 1990), analyze catalogues of design precedents and even solve the problems of shape recognition and transformation (Liu, 1994). This essay is developed based on Neural networkss and related information.

There are some limitations in simulating the style of Neo-Plasticism of Mondrian:

1.Color: Color is very important is Mondrian's works. However, in this research framework, color should be discussed in a more abstract dimension because it is regarded as unique characteristic.

2.The width of line: The are some different width of lines in Mondrian's works. The width of lines is a key element of balance and harmony in Mondrian's work. However, most of the works selected in this research have the same width of lines because of time-saving for Neural networkss operation. If both hardware and software were improved, it is possible to create different width of lines.

3. Connectionist Computation in Design

Neural networkss can be categorized in types by different calculating and constructing methods. Two layers of PA networks had been used to solve the problems of Architecture (Coyne and Newton, 1990; Coyne, 1991). According to Coyne's research on PA network, basic design characteristics can be described by a connectionist computation model whether or not if those patterns are complete. Such capability of integration and categorization is very useful for design because design sketches were always done roughly and design characteristics were not well defined in the earlier design plans.

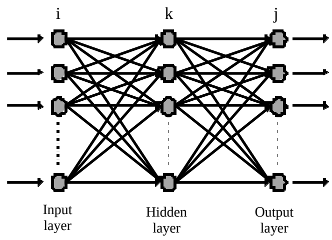

Figure 1. A typical multi-layered back propagation network.

However, if PA networks were lacking a hidden layer, the capability was limited. When too much difference and too little overlap between the structure of input pattern, the proper reaction can not be produced. In "Perception", Minsky and Papert mentioned exclusive or (XOR) in which two-layer structure of PA networks could not work (Minsky and Paper,1969). In design field, there are many problems just like XOR. The Back- Propagation Network can easily solve XOR problems because it contains hidden layers. As Minsky and Papert mentioned, hidden layers can provide interaction among similar patterns from input to output of units (Liu, 1996).

In Liu's research, multi-layered back propagation networks can successfully simulate shape recognition and transformation of designers, which improve the experience of designers would influence their capability of recognizing hidden sub shape.

4. Training and Learning

In order to get the result easier, there are eight homogeneous works selected as examples for this research. These eight works were done by Mondrian from 1929 to 1932. Works 1-7 are models of Neural networkss. In other words, they are the "knowledge base" of Neural networkss. The eighth work is the test model of well-trained Neural networkss. In order to transform Mondrian's works to "0" and "1" which are acceptable to Neural networkss, these works were transformed to 400X400 bitmap. As for the interaction between input and output, the main rectangles in the works are inputs and Mondrian's works are outputs. The relationship among works, bitmap, input and output is as Figure 2.

Neo-Plasticism of Mondrian went back to the principle of Plasticism, even to be ascetic and got rid of anything related to emotion and nature in order to reach the art of pure plasticism and total abstraction. From 1920, Mondrian tried his best to correct the misunderstanding of treating his art as Geometry. He insisted that his works were created from his instinct but rules. Therefore, it is inappropriate to apply organization, mathematics and geometry to his works.

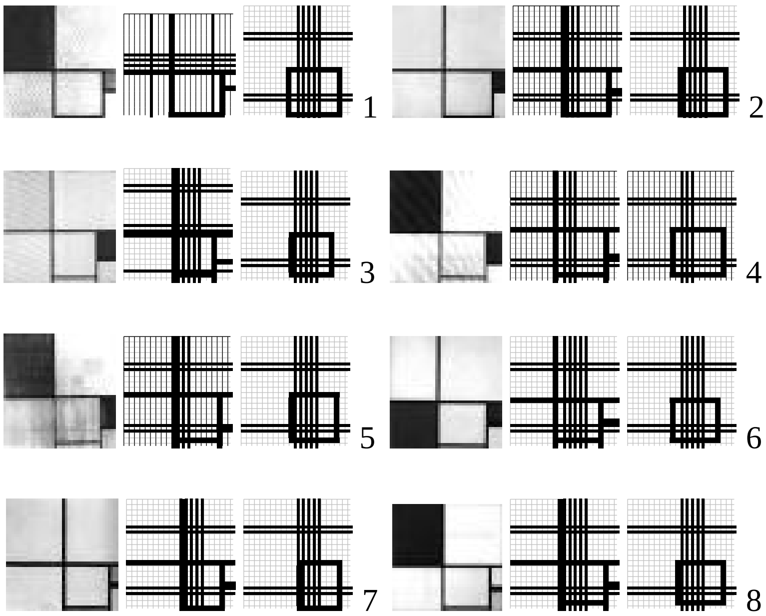

Figure 2. Patterns 1-8. Pattern1-7 are the learning patterns for neural networks. Pattern 8 is for testing. From upper to lower: Mondrian's works, their bitmap (output) and input bitmap. pattern 1: Composition II with Yellow and Blue, 1930. pattern 2: Composition with Yellow and Blue, 1929. pattern 3: Composition with Yellow and Blue, 193. pattern 4: COMPOSITION A; Composition with Red and Blue, 1932. pattern 5: Composition with Yellow, 1930. pattern 6: Composition A, 1932. pattern 7: Composition No.I, 1931. pattern 8: Composition No.II; Composition with Blue and Yellow, 1930

From existing sketches of Mondrian, it is difficult to judge the order of lines in his works. In this research, a rectangle was transformed to Mondrian's works, which could approve the relationship between mathematics and geometry with Mondrian's works although it was disagreed by Mondrian. In addition, a rectangle also matches what Mondrian thought: "all bases of structure are horizontal and vertical framework". In other words, rectangle as well as association and principle of Neo-Plasticism.

When units of input and output were decided, the variables inside Neural networkss should be set, such as number of hidden layer, learning rate etc.

For example, one hidden layer, 100 units and learning rate 0.001 were set. After 14319 times of training and learning, the system was well trained.

5. Testing

In order to confirm Neural networks learning completely and match the transformation of Mondrian's work, some patterns in the system would be sampled as input. Put the bitmap value of this input into the system and confirm it by the output. As picture 3, put patterns 5 and 7 into the Neural networks, the output matched Mondrian's work.

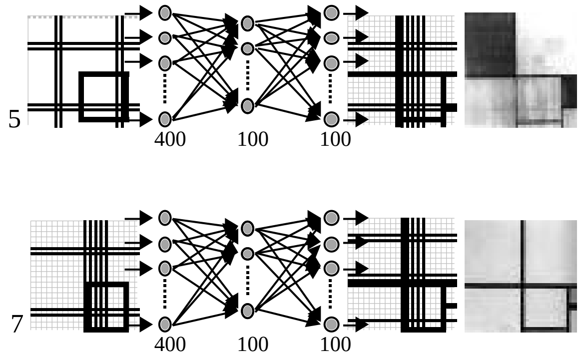

Figure 3. Test 1 is for testing well-train network. Take pattern 5 and 7 as examples, after input and through the process 400-100-400 back propagation network, the result is as above.

Secondly, pattern 8 was put into the system. This pattern is also more homogeneous in Neo-Plasticism Mondrian's work, however, it has not been learned by the networks. The input process and output is as follows:

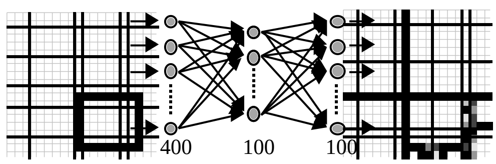

Figure 4. Left is input bitmap, right is output bitmap. It is shown the output is incomplete on the right bitmap (the darkness is the strength of nodes).

From the bitmap of output in picture 5, the nodes in the right lower corner have different strength. They could not construct the vertical and horizontal structure of Mondrian's work.

In the related research of picture recognition of Neural networks, there are several methods to solve the problem of incomplete output:

1. Set TRA (threshold of recognizing activation) value (Liu, 1996):

To set a value as a threshold value and test the value of each node. It is 1 if the value is greater than TRA and 0 if smaller than TRA.

2.Add external variables (Amitara Datta and Tamaltaru Pal and S.K. Parni, 1997):

To add variables in the proper position between nodes and bitmap and calculate by mathematics programs. It could sweep each node and improve the bitmap after each sweep.

In this research, the method of TRA value setting can directly and simply solve the problem created by the artificial neural networks system described above. The TRA reflects the experience of designers. In other words, the more experienced designers will tend to set lower TRA values. Therefore, they can identify more hidden subshapes, and vice versa. The problem solving experience of designers can be judged by the TRA value they set. Theoretically, it is quite suitable to use this model to simulate human-related vision behavior, however, it might not fit in Mondrian's painting and designing behavior.

This research is based on the methodology induced from the painting principle of Mondrian's Neo-Plasticism. The line position is determined by STV (straight total value). To explain this more clearly, we can add up the values of the incomplete bits vertically or horizontally in a line in the bitmaps generated by output. We call the sum as STV value. We then compare the value with the STV value of adjacent lines. The line with the greatest STV value will determine the final line position.

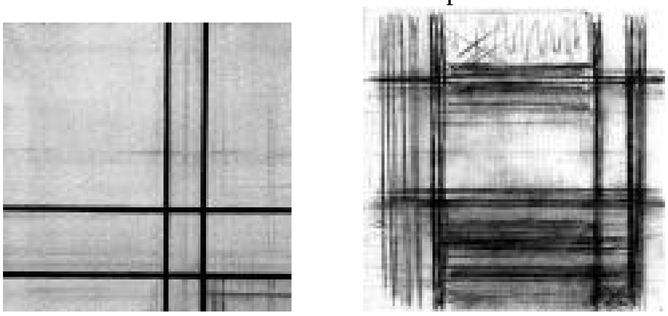

Figure 5. Left: Composition with Yellow (unfinished). Right: Composition (study).

While we are working on creation and design, sometimes we spend a great deal of time trying to optimize the position of one simple line, even when the change is incremental. We evaluate the effect of the position of each individual line back and forth on the draft. Finally we decide the exact position and organization based on experience and plot the line heavily on the draft. This line is the line with the greatest STV value. We can find this from Mondrian's study or incomplete work as illustrate in Figure 5.

In Mondrian's study and incomplete work, the thick lines represents lines with greater STV value. The adjacent lighter line is the line with smaller STV value. All these lines are all generated by Mondrian based on his creation experience (for example in Neo-Plasticism period) and creation objective (Neo-Plasticism's spirit and principle). To conduct neural networks simulation, we can use the work of Mondrian Neo-Plasticism period for our learning and training. After checking STV value of the structure generated by input, the work similar to Mondrian Neo-Plasticism can then be generated.

After comparing the strength of STV value, output of picture 5 produced Mondrian work in 1930 which has not been learned by Neural networks. The process is as Figure 6.

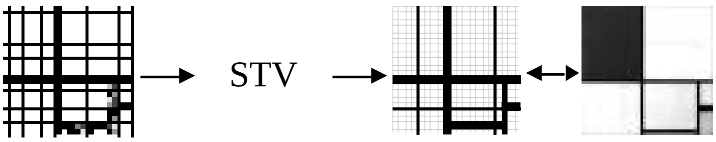

Figure 6. After comparing the strength of STV, the structure is the same of Mondrian's work.

Neural networks successfully produced Mondrian's work. There is another test: to input a rectangle of non-Mondrian, the bitmap of its output is "incomplete". Through STV screening, the process and result is as Figure 7.

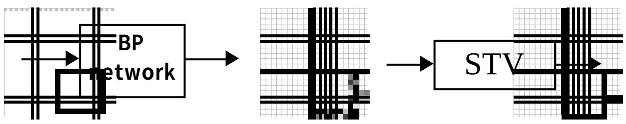

Figure 6. The process of produced Mondrian-like bitmap.

Test 3 produced Mondrian-like bitmap.

6. John Hejduk's Architectural Floorplans

Mondrian's paintings have had a profound influence on Architecture. In addition to architects of De Stijl, two famous architects, T. Aida and J.

Hejduk, have also shown in their work the perpendicular architecture structure. In "House of Mondrian Pattern", Aida used the two of Mondrian's paintings, "Rhombus" colored surface with a Gray Picture (1919) and "Composition in Black, White, and Red" (1939-42), as building models of a house and its base. through this "wisdom game" Aida tries to probe the possibility of transferring 2-dimensional structure to 3-dimensional architecture structure, and also to probe the problem of setting unification from opposite elements (Aida,1990).

Hejduk once was addicted to Mondrian's rhomb structure. He especially paid attention to the characteristics of form and space, e.g. the tension of edge and corner, and the expansion of boundary. In order to understand the meaning of these characteristics in architecture, Hejduk conduced three so-called "Diamond" experiments in 1963 and 1967 at two residences and one museum. These three cases formed his "Diamond Projection System". Hejduk thought that this was a new way of inspecting form and space (Hejduk, 1985). In comparison to the projected space of the Renaissance, the Diamond Projection System recognized the value of 2-dimensions and tried to pass it to the audience.

Hejduk regarded his creation as 7 periods. Mondrian's influenced his second (1954-1963) and third (1963-1967) periods. In the third period, Hejduk concentrated on rhomb structure. Hejduk recalled his experience of understanding Mondrian: "When we walked by the tulip field, I started to understand Mondrian....not the color of tulip, but the area of root. The density of sand and ground made me think of Mondrian. It was the non-transparent atmosphere. In that area, the earth and the ground are too close to be transparent" (Hejduk, 1985). In fact, when Hejduk designed Texas House 3 in the second period, he had started to research Mondrian's structure concept. In that period all floor plans are horizontal and vertical. Some surfaces even contained geometric structure. Mondrian's influence became weaker in the third period.

Take works of John Hejduk in the second and third periods as examples. Use simulation of 3 Mondrian's works or part of his works as input and 3 John's architectural floor plans as output. Then, transform them into bitmap in order to establish the new model of Nerual Networks.

As shown, for saving the learning and training time of neural networks, the structure of bitmap is 225-BY-225. That is , every bitmap is 15X15.

Repeat the same process. Set one hidden layer as 150, learning rate 0.05. After 15369 times epoch, the system was well-trained. In other words, put M1, M2, M3 into the system, it could get H1, H2 and H3. It not only confirmed the system was well-train, but also initially provide the possibility of applying Neural networks on architectural floorplans.

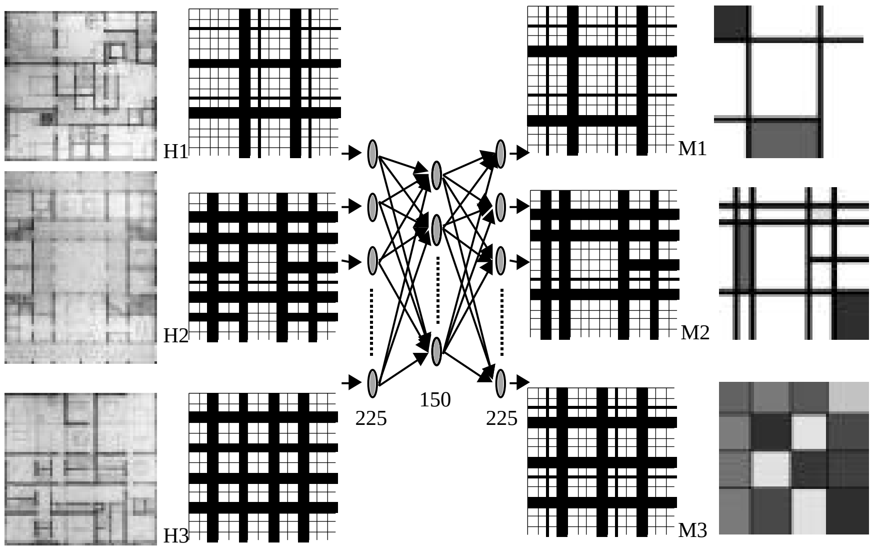

Figure 6. MH neural networks system. H1:Texas House 7. H2: Texas House 3. H3: Apartment House. M1, M2 and M3 are the simulation of Mondrian's works.

However, it is still difficult to prove the possibility in this research. Although John Hejduk claimed several times that his works were influenced by Neo-Plasticism of Mondrian, research for the relationship of both is not enough. Therefore, MH neural networks could only simulate Mondrian's works as input and simplify John Hejduk's architecture floor plans by marking the main structure as output. If other research could complete this part, MH neural networks will be more mature.

7. CONCLUSION

In this research, we discussed the interaction between design behavior and connectionist computation by simulating Neo-Plasticism Mondrian's works through neural networks. Although the Back-Propagation Network simulated Mondrian's works successfully, it is still not strong enough to discuss design behavior. It is no doubt that neural networks could store and learn which dominate the "experience" of human beings. This research used rectangle as input and Mondrian's works as output. Then, Neural Networks stores and memorizes Mondrian's experience to be its own experience. However, it is quite weak to induce a "rectangle" to Mondrian's works directly. Nevertheless, we did not know Mondrian's creation process in the Neo-Plasticism period, therefore, use the main part of his works - rectangle as input to match the principle of Neo-Plasticism. In addition, the learning and training process of Neural networks is too time-consuming. Although hardware and software is important, the number of nodes and hidden layers have great influence as well. Although picture is very important in designing field, we should reduce data size to save computing time. For example, in the research, we reduced the number of input patterns as 7, 20*20 each, 400 nodes in total, 100 hidden layers and got 7 output patterns. It is to prove that the precise position of the line could be induced by computation of neural networks. Hence, in following MH network, we reduced the number of nodes to be 15X15, 225 in total for time-saving.

After the initial discussion of the second part, the application of neural networks in design theory and creation could be developed further by other related theory.

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