



Interactive Visualization Design of Neural Network Based on Visual Thinking

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Abstract: The development and cross-fusion of visual thinking, artificial intelligence and visualization technology have improved and expanded the three technologies, and the use of visualization technology to help build and optimize the agent model has also become a hot topic in current research. In order to solve the interpretive problem of neural networks and help users to construct, train and optimize the structure of neural networks, this paper designs a visualization scheme for the modeling and training process of artificial neural networks based on visual thinking.

[Xu Chengzhi, Xue Yongzeng. **Interactive Visualization Design of Neural Network Based on Visual Thinking.** *J Am Sci* 2023;19(4):43-49]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). <http://www.jofamericanscience.org> 04. doi:[10.7537/marsjas190423.04](https://doi.org/10.7537/marsjas190423.04).

Keywords: Visualization; neural networks; visual thinking; interaction; human-computer interaction; artificial intelligence

Introduction

Neural network is a mathematical model that simulates the structure and function of human brain. It has a strong ability of self-adaptation and self-organization and is widely used in many fields, but because of the characteristics of non-linear non-convex, huge parameter and complex hierarchical structure, neural network cannot play its role in some high-risk decision-making fields.

In recent years, the application of visualization technology in the field of neural networks has become one of the research hotspots. The aim of visualization is to present all kinds of data more intuitively by means of graphic images, 3D models and so on, so that human beings can understand and accept the information more easily. The information visualization has built bridges between people and data systems such as computers, the use of human inherent pattern recognition ability to graphic information to help, assist analysts in accurate analysis, judgment and reasoning (AMiner,2019).

Furthermore, with the help of the related theories of visual thinking, the neural network-oriented visualization can develop more abundant data presentation forms, manifest data presentation effects, and adapt to more kinds of network structures, therefore, it is necessary to study the combination of visualization technology and neural network.

Visualization of artificial neural networks

The concept of artificial neural network was proposed by MC Culloch and Pitts in 1943(Mc Culloch and Pitts,1943). After years of optimization and development, neural network becomes more and more powerful, and has been more and more applied in fault detection (Shaimaa,2016)(Sayyed and Mehdi,2021), stock market prediction(Ye et al,2021) and other fields. At the same time, the structure of neural network is becoming more and more complex. It is difficult to design and understand the neural network because of its nonlinear and highly redundant characteristics and the abstract characteristics of the data meaning of each layer. This causes the user not to be able to have a clear insight into the network structure, and has caused a great trouble to the creation and optimization of the neural network.

On the basis of visual information, visualization technology makes use of graphics, images and tables, which are more acceptable to human beings, to display the complex external information in a unified graphic way, make it easy for people to understand and remember. Due to the high acceptability of human visual information, "Visualization" has become one of the research hotspots to solve this problem.

Wang et al have designed an online interactive visualization tool, CNN Explainer, which provides a convolutional neural network explanation to help users understand CNN's underlying components, check and design convolutional neural network, however, the planar representation has obvious limitations for the

representation of complex neural networks(Wang ,Turko and Shaikh,2020). In 2022, Stefan Sietzen, a Viennese scholar, also studied the visual design of graph neural networks, explaining the definition of neural networks intuitively.

In the process of design research, visual thinking has been applied more and more, and gradually shows the feasibility of its application in the field of neural network visualization: on the one hand, in essence, neural network is composed of neurons and their connections, and its materialized presentation is highly related to its own definition, so it is reasonable to use visual information to explain neural network On the other hand, the structure of neural network is very complex, a large number of neurons and connections can easily lead to layout confusion, focus dispersion and other problems, and the use of visual thinking related processing methods, can make the display effect more clear, more in line with the original intention of this design.

Visual thinking

1. The concepts and characteristics of visual thinking

Visual thinking, also known as Visual perception, was Rudolf Arnheim by American art psychologists on the basis of cognitive psychology. It is a kind of creative thinking activity that combines rational thinking and visual perception, and it is also a universal thinking form with high selectivity and creativity.

Rudolf Arnheim, in his works “Visual thinking” and “Art and perception”, mentioned that visual thinking is characterized by creative thinking, it is characterized by the explorative ability of direct perception of objects, the flexibility of direct manipulation of visual images, and the Unconscious mind characteristics of induced intuition(Jin,2017).

2. The cognitive process and tasks of visual thinking

The cognitive process of visual thinking includes four stages: visual detection, visual attention, consciousness and memory, which are responsible for information detection and reception, screening, processing and sorting, input and storage(Mark and Ernest,1993)(Figure 1).

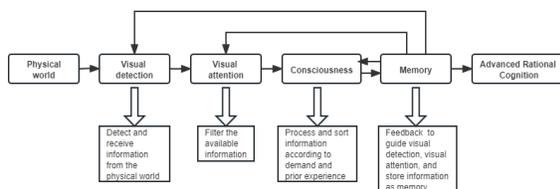


Figure 1. visual thinking cognitive processes and stages of the task

Visual design principles for neural networks

In visual design for artificial neural network, we should follow the basic principles of visual design and consider the particularity of neural network, and sum up the pertinent principles that accord with its characteristics.

1. the basic principles of visual design

The principles of visual design have been greatly influenced by Taft's graphic principles and Gestalt theory:

(1) Graphic Integrity:

Select proper coordinate baseline, coordinate axis scale and scale coding, divide space reasonably, avoid data distortion.

(2) Design Aesthetics:

Use the smallest amount of space and the smallest amount of ink to present the viewer with the largest number of ideas, that is, maximize the data-ink ratio and maximize the data density. Of course, the excessive data density will cause the user to obtain information inefficient, layout confusion, and affect the user's experience, so it is not desirable.

(3) Use hierarchy and segmentation:

Through the division of the level and the division of the space area, all kinds of information are put in the proper position by the clustering thought.

(4) The combination of text and graphics:

Diagrams mainly include diagrams, tables and graphic symbols,etc. A comprehensive combination of text and diagrams can make information more comprehensive and clear, and more user-friendly understanding.

2. aiming at the visual design principle of neural network

(1) The hierarchy of relative relations

The relationship among the factors in the neural network is one of the important parts to express the structure of the neural network. The basic relationship is that layers contain neurons, and there may be weights between neurons in adjacent layers.

(2) The foldability of the data presentation

The parameters in the neural network are very huge, if all the data are visualized in a static way, it will inevitably lead to layout confusion, poor user experience and other problems, it violates the fundamental principles of visual design. Therefore, it is necessary to collapse part of the data and turn it into user interactive expansion to get detailed information.

(3) The interactivity of system elements

For the visualization design of large data, the traditional one-way information transfer scheme has been difficult to meet the needs of users. Users need to get up-to-date, dynamic and interactive data information in a timely manner.interaction design can give more

function and meaning to visual design and provide better user experience.

Because the display of neural network structure is completed in the way of three-dimensional model, and a large number of three-dimensional models will have the problem of mutual occlusion, therefore, it is necessary to implement interaction design that adjusts the view angle, element size and spacing. In addition, the network structure and parameters need to be presented in detail, and depending on the nature of foldability, some information is collapsed by default, so by interaction, selectively expand, fold the detailed data display interface can not only make the layout more concise, but also become the solution to “Maximize ink proportion and data display incomplete conflict” preferred solution.

Analysis of visual design for neural network

1. the core elements of visualization

From the overall structure, the neural network contains three main elements: layer, neuron and the weight between neurons, and there is a close inclusion relationship, these three also contain the vast majority of the information in the neural network. Therefore, taking these three elements as the core elements of visual design, not only can keep the characteristics of each element while showing the data of neural network, but also have a very natural relationship between the elements.

2. the presentation of visual elements

The neural network layer can be divided into three types: input layer, output layer and hidden layer. The input layer and the output layer are relatively simple, generally only one layer, each layer has one or more values of the transfer. The hidden layer is the main part of the neural network, and is also a very complex part. For different types of neural networks, there may be different kinds of layers, such as pool layer and convolution layer in the convolutional neural network. In the visual design process, the neural network layer can be understood as a surface, representing a collection or container of several neurons.

The weights between neurons and between neurons can be understood as nodes and connections respectively in the visual design process. There are zero to many links between adjacent nodes, each link has different weight value, can be positive or negative, indicating the positive and negative correlation between nodes and the degree of correlation.

3. the visualization technical scheme

This paper is a visual design of neural network structure and its related data parameters. Since a complex neural network may require millions or more of neurons to render, and the number of weighted connections between neurons is much larger, the

requirement for rendering capability and performance is naturally very high. In this respect, the Unreal Engine has a distinct advantage. It is a 3D model rendering performance, strong performance, high scalability of the game engine, for the UI interface rendering and performance effects and user interaction support are also done well, very suitable for 3D model rendering, interactive design, visual design of the implementation.

Combined with the above analysis, the scheme is implemented by a combination of Unreal engine, Python and C++ Tools. Python is mainly responsible for building, training, saving and exporting the neural network model, while C++ is mainly responsible for parsing, processing and transmitting the model data. Finally, the Unreal engine is responsible for visual presentation and the implementation of interactive interface, interactive logic and feedback (Figure 2).

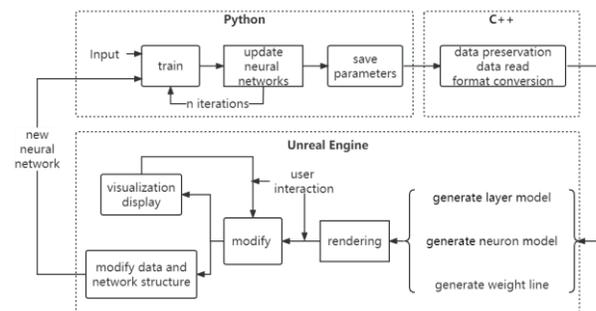


Figure 2. Technical solution flowchart

Neural network interactive visual design practice based on visual thinking

Visual thinking is a method of conveying information with pictures and words. Visual information is often more expressive than directly describing it with words. The aim of visual thinking is to express information in symbolic, logical and structured visual form, which can be used as a concrete statement of abstract entity to reduce the comprehension deviation.

1. Visual design

In the process of visual design, using visual thinking can better facilitate data analysis and understanding, design data presentation and interaction methods, determine design principles, improve user experience and feedback, and ultimately develop suitable design solutions and better present data.

(1) Mapping relationship based on information needs and prior experience

In visual design, mapping relationship refers to the way and rules in which the features of the data are mapped onto the visual interface. The correctness, effectiveness, and efficiency of user identification of mapping relationships are key to ensuring the quality of visual design and user experience. According to the

theory of visual thinking, People's information needs and experience are the important factors that affect the processing of visual information. With these two points, users can easily understand and identify the meaning of symbols, thus more accurate and efficient access to data information.

In the relevant field, neural networks generally include several important hierarchical structures, such as layers, neurons, and weights between neurons, it is easy to establish the mapping relationship with plane, sphere and curve under the premise of the visualization

information demand and the prior experience. Therefore, considering that users generally have a general understanding of neural networks, the layer structure in the neural network is designed as a semi-transparent square patch, the neuron is designed as a sphere, and the weight between the neurons is designed as a curve with a certain thickness, the red and blue colors with strong contrast are selected as the positive and negative weight curves respectively, so that users can easily distinguish the weight relations(**Error! Reference source not found.**).

Table 1. Semantic table

Geometric form	Sample	Semantic	Remarks
Sphere		the default state of neuron	
Sphere		the selected state of a sphere or neuron	
Surface		the default state of the layer	in order to solve the occlusion problem, the surface is translucent (same below)
Surface		the selected state of the layer	
Curve		curve between neurons (weight is negative)	to make it easier to select, add a rhombus to the middle of the line for clicking on (same below)
Curve		curve between neurons (weight is positive)	

On this basis, users do not need to spend too much energy learning neural network structure and visual information between the corresponding relationship, but can naturally find their own information, for the visual display and user interaction have played a good role in the promotion.

(2) Focus on the visual differences

When receiving visual information, people will unconsciously pay attention to the difference with other information. The difference of visual information determines the ability of the target information to attract the eyeball of the observer (Colin, 2008), which greatly affects the probability and proportion of the attention screening and the target information being obtained. Therefore, we can make the target information stand out from all the information by reasonable design of visual difference (Figure 3).

It lists the differences in visual information in terms of color, size, position, shape, and blending, and gives some simple examples. It can be seen that the differences in various visual information can indeed make the target information more prominent, especially the color differences, shape differences

and the combination of the two differences. Of course, the difference should not be abused, otherwise it is easy to cause excessive distraction of user attention, but can not focus on the target information.

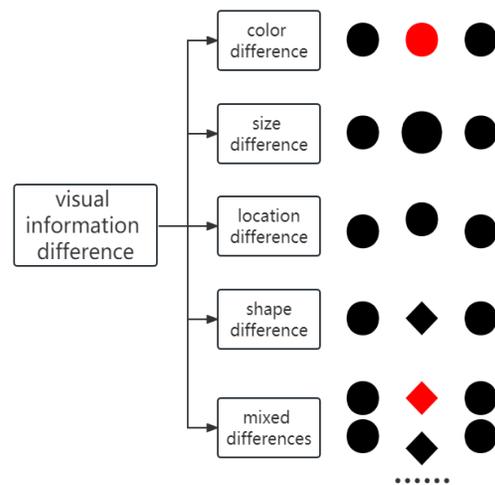


Figure 3. Differences in visual information

For neurons with different degrees of contribution, so that they show a different sphere radius, the sphere radius of the value and its contribution is proportional to, and limited to a certain range. For different weights, make it show different color and line thickness, red and blue color with strong contrast, respectively, the weight of the positive and negative, line thickness, respectively, the size of the weight value.

In addition, when the user interacts with layers, neurons, and so on, the interactive elements will show differences. For example, layers, neurons, and so on will have special light effects after they are selected, (Table 1), this gives the user feedback on the selection and improves the user experience.

(3) Collocation of points, lines and surfaces

Visual communication is the process of visualizing information through visual symbol language. From the perspective of visual communication, the basic elements, such as point, line and plane, are the important elements to constitute and reconstruct the visual program.

The point element is the simplest form, used mostly for location and aggregation. The line element has the division and the directivity, may cause in the work the element to have the primary and secondary clear spatial sense and the strong guidance function. The area occupied by surface elements is the largest, with a strong visual expression and impact, in the closed profile to give a clear, prominent feeling. The use of these basic elements can accurately display and convey information, so that users can understand the meaning of visual language communication.

2. layout design

In the design of interface layout, visual thinking can help designers better understand and analyze the needs of users, and make a reasonable design based on this.

(1) Prioritizing visual processes and information

There are differences in visual attention within a certain range, the best visual field is located in the top, left, left and middle of the picture, and the middle attention is stronger than the surrounding edge. The visual flow is the user's visual attention transfer process, generally from top to bottom, left to right (Figure 4).

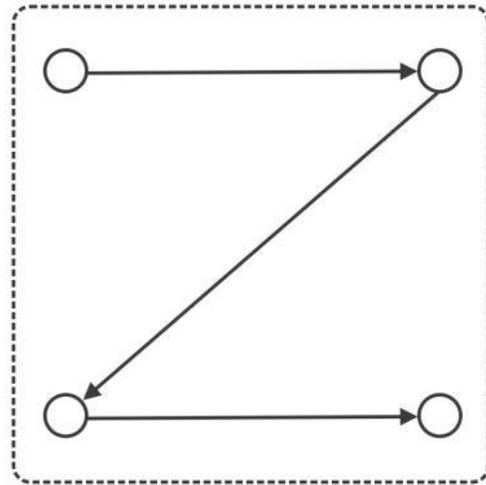


Figure 4. Type Z browsing mode

When you receive visual information, you usually start with an overview of the whole and then focus on the parts of interest. This is useful for visual layout design and information display location, and the target information should be placed in the most eye-catching view, and let other information according to priority distribution in accordance with the visual flow of each visual field, in order to achieve better visual guidance effect.

In visual design for neural networks, the structure and weight parameters of neural networks are the most noticeable and the most needed target data for users, therefore, the 3D model of the whole network is placed in the upper left position, and the concrete data of layers, neurons and connections are displayed in the lower left position. The operation panel with interactive button and adjust network display option button has some particularity, that is, when the scene is empty at the beginning, the user needs to pay attention to this operation panel first, so it needs to be placed on the left side, and has a more prominent form of expression. After the network is generated and adjusted, the user's demand for the operation panel is reduced, and the target information is transformed into the network structure. At this time, the operation panel is placed on the lower right side. Thus, when the picture is refreshed, the user will browse according to the network structure, the concrete data, the Operation Panel's approximate order, conforms to the design requirement.

(2) Relevance

The application relevance, can let each visual element produce the natural echo, can let the user form a complete visual chain in the mind, can

enhance the user experience and the visual expression effect.

In general, the use of font and color, kerning, and typography and other visual elements in series, in order to assist the formation of a visual chain.

(3) Hierarchy and information interference

The interference information is the information which is independent of the user's current demand. It will affect the accuracy of the attention mechanism screening and distract the user's attention. To avoid distracting information, you need to weaken irrelevant background and irrelevant information. In addition, there are some non-relevant information to the understanding of the target information to help, so the weakening of this information should be special treatment, so that it is not too distracting, the auxiliary effect does not disappear completely. In addition, from a visual thinking point of view, the design of interface hierarchy and simplification is also of great importance because of the need to focus on the accurate transmission of information when designing an interactive interface.

By default, users focus on the network structure rather than the data information, so the data information section is designed to pop-up and shows only a small amount of summary information by default, the goal here is to prevent the panel UI from distracting the user from the target information. When the user wants to see the data information, the pop-up shows all the information and the background of other unrelated plate fuzzy processing, related auxiliary information (such as network structure) to weaken the processing, the goal is to direct the user's attention away.

3. interaction design

The application of visual thinking can better understand user requirements, follow basic interaction design principles, analyze interaction data and create effective design solutions to improve the user interaction experience of digital products and applications. Therefore, in the design process of any digital product or application, visual

thinking should become an indispensable part to achieve more successful design results and higher user satisfaction.

(1) The need for interaction design

For the neural network, its parameters are very huge, and the data with a large number of dimensions can not be presented in a good form at the same time, not suitable for static graphic display, otherwise, the data density will be too large, the cost of information acquisition is too high. This both loses the meaning of visualization and affects the user experience.

Interactive design can provide more extended functions and meanings for visual design, and let users participate in the process of data exploration and analysis, so as to better understand the inherent relationship and characteristics of data, the realization data information fast, the accurate presentation and the transmission. Through a good user interaction and feedback design, not only can more detailed display of data, to provide users to modify the structure of the neural network and parameters of the function and feedback, it can also make users more convenient to use and operate the visual design to achieve better results, thus improving the user experience and satisfaction.

(2) Interaction design

Interaction design is embodied in "Neural network structure", "Data" and "Control Interface":

In the interaction with neural network structure, layer elements, neuron elements and weight elements are all interactive elements, and the interaction results will affect the structure and parameters of neural network in reverse.

Interaction with the data, mainly in the acquisition of data information, can be based on personal experience to decide on data deletion and other operations.

Interaction with the control interface, you can determine the overall flow of visual operation and set options, including display, change, end of the process control.

The final result is shown in

Figure 5.

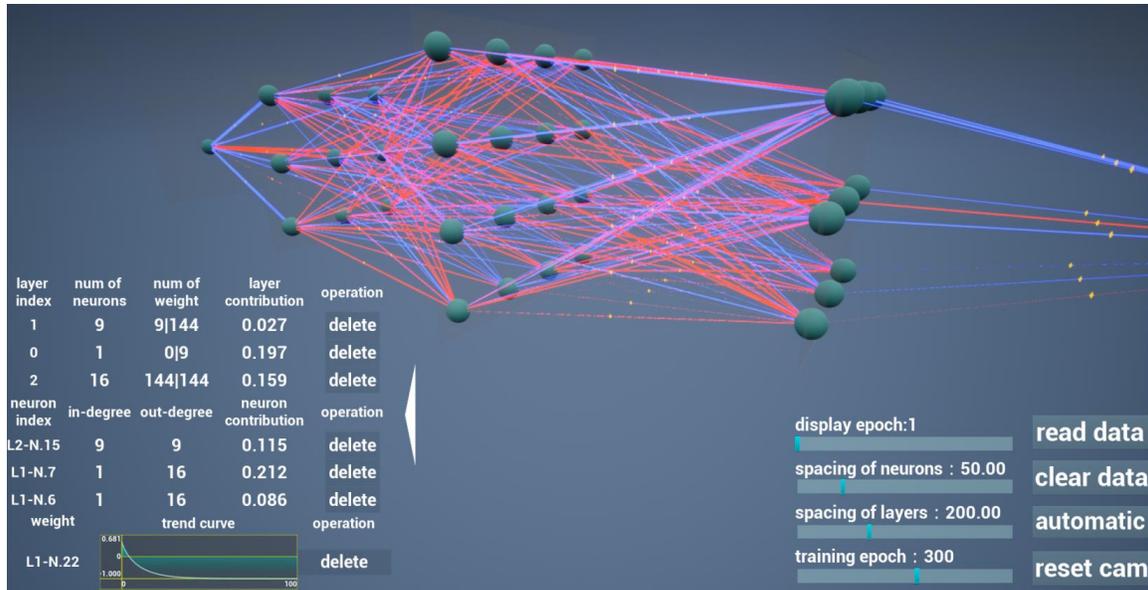


Figure 5. Entirety figure

Discussions

In order to explain and understand the specific structure and optimization direction of neural networks, visualization becomes the only choice. In this paper, the structure and important parameters of artificial neural networks in the process of creation, training and optimization are presented in an interactive 3D visualization, based on the visual thinking, the display scheme and layout design were optimized and improved. It provides some convenience for users in the process of neural network creation, and also provides a train of thought for the visual design of neural network.

Foundation item:

Supported by Heilongjiang Provincial Philosophy and Social Science Foundation of China (Grant No. 22TQD360).

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3/21/2023