IMPACT OF DESIGN TOOLS WITH GAME-LIKE FUNCTION ON DESIGNER

REIKA. SATO, BIN. LU
Osaka Electro-Communication University / Department of Digital Game, Japan
Software School of Fudan University,China
Email address: sato@dg.osakac.ac.jp; lubinna@hotmail.com

AND

Mayumi, Oyama-Higa. Tsuneo Jozen, Katsuya Nagae
Graduate School of Humanities and Department of Integrated Psychological Sciences Kwansei Gakuin University,Japan
Osaka Electro-Communication University / Department of Digital Game, Japan
Email address: jozen@dg.osakac.ac.jp; nagae@dg.osakac.ac.jp

Abstract. Various visualization design tools such as CG and VR have been widely used in the process of architectural design and urban planning. The applications of these tools not only assist the designers but also make it possible to involve other relevant professionals and ordinary residents. In order to enable more convenient applications of the tools in the design process and instigate the interests of additional parties of relevance, we add entertainment function to the design tools. In order to test the results of such design tools resembling computer games, we examined the status of users during the design process when these tools being employed. Comparison of the results of questionnaire and collections of physiological data indicated the unique effectiveness of game-like design tools. Pulse detection at ear was used to check the changes of blood supply for left and right hemispheres. The data collected were then visualized by complex Chaos analysis. Comparison of the processed data indicated the different brain status when a user applies these tools in the design and showed the effectiveness of the tools and their impact on the designer. Our results support the usefulness of game-like design tools and may lead to further developments of contents and methods to advance such tools.

1. Introduction

A variety of essential factors and conditions need to be considered during the process of architectural and urban planning design. If many such factors and conditions can be presented by tools enabling direct visualization and used directly in the design process, a platform facilitating easy comprehension through direct-viewing methods may be established for designers as well as other relevant parties. Technological developments for enabling visualization tools such as computer graphics (CG) and virtual

reality (VR) have already been widely applied in the field and their usefulness has been fully proven.

We have applied many such tools in our design process. However, because until now CG and VR applications still have many limitations such as operating mode and degree of difficulty for comprehending the presented picture, we add some game-like operating functions onto enabling visualization tools in order to stimulate interest of the user and simplify the application. Our study demonstrates that these game-like functions allow the designer more easily display his/her ideas and that other relevant parties may more easily reach consensus with the designer on his/her design. In addition, non-specialists may also participate in the design process, comment on the display and enjoy the operating functions.

2. Examples of Applying Game-like Enabling Visualization Tools

a. Victory Avenue, Shenyang

The Shenyang Victory Avenue project is a government-sponsored old city renovation. The avenue is a major street of the city with a glorious history. Therefore, many historical buildings should be preserved. However, due to the lack of comprehensive urban planning for a long period of time, many spontaneous buildings co-exist along the street, which contributes to the chaotic vista. In order to plan the renovation fully, the 6-kilometer street was divided into 6 large blocks with different commercial and residential purposes. We then used virtual reality enabling visualization tool to simulate the present situation and future development of each block, and demonstrated the future scenery of the entire region with CG effect chart. Simultaneously, both the present and the future landscapes could be seen in virtual reality, and the details of every building on every block might be observed by walk through or fly through operation.

In virtual reality, in order to specifically observe the impact of new buildings on the preserved buildings, we carried out various adjustments on new building design, for instance, on height and position. This part of adjustment used interactive game-like function - the user might operate directly with the mouse, as if willfully played in the space.

We discovered enthusiasms of users for the game-like construction or modification of buildings in virtual reality to observe the impact of buildings on space and environment. The game-like functions stimulated the user to probe each adjustment and to consider its impact and effect.

Fig.1: Victory Avenue Effect Chart (CG)

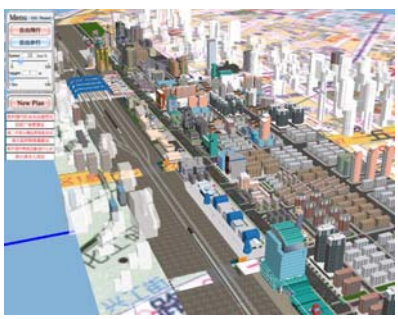

Fig.2: Victory Avenue Virtual Reality

Fig.3: Building Adjustment Operation

b. Urban Planning of Nanhu Region

The Nanhu region is a new part of Shenyang city with many planned commercial and residential areas. As a key point of transportation of the region, the multi-level crossing bridge at Wenhua Road is frequently subjected to severe traffic congestion due to the large volume of vehicles as the results of the nearby IT wholesale market for northeast China at Sanhao Street and being a part of the major transportation route of Shenyang. The poor design of the bridge aggravates the problem especially at the peak time. Therefore, transformation of this multi-level crossing bridge is vital to the traffic condition, the layout and the landscape of the entire region. We used virtual reality technique to carry out simulation of traffic condition at the Wenhua Road multi-level crossing bridge to fully resemble the detailed situations at all four levels, and analyzed the causes of traffic congestion. In addition, we simulated the landscape effect if this multi-level crossing bridge were demolished, enabling its transformation design process be like game playing.

In virtual reality, the simulation of four streams of traffic at the multi-level crossing bridge was conducted based on the authentic traffic regulations. Users could place themselves in the actual transportation environment, glance over completely four levels of the bridge following real highways, and sense strongly the authenticity of the game-like stimulation. Likely, the transformation of the multi-level crossing bridge even more resembled playing game for its demolition and modification. The game-like functions greatly encouraged the participation of the general public. Our various tests on users also enabled better understanding of responses of people facing heavy traffic, and further insight on the pressing situations of different transportation structures.

Fig.4: Multi-level crossing bridge tentative plan *Fig.5*: Grade crossing tentative plan

c. Three Dimensional Database of House and Room Disposition

The database is a collection of house and room interior disposition samples. It may be used similarly as various kinds of three dimensional databases. We added the samples into the 3D database and users might freely dispose any item from the database to desired position. The operation was like playing game in virtual space. Both the designer and the house-owners might propose the interior arrangement of a house and/or a room. The participation of the house-owners facilitated their more detailed and clearer requests to the designer. Such operating mode could also be useful for product promotion of many kinds. Companies can explain the use of a product and allow the buyer appreciate fully its function and results virtually before purchase. It is advantageous for comparison of products as well.

Fig.6: Various kinds of Furniture Disposition

We offered the play function to the above-mentioned three projects like the game. When the user operates them, they change or adjust various aspects, they feel that is easy play, interesting and curious. To understand the state of the mind and body, we proved play was effective by collecting and analyzing living body information further though it was certain that they were interested in play.

3. Application and Evaluation of Real Time Simulation In Virtual Reality System

We collected physiological information from some users during their operation of virtual reality system. By analysis of these data, we deduced brain states. Comparison of brain states of users when carrying out passive animation induction and interactive game-like operation indicated that game-like operation excited the brain far more intensively than passive observation of animation.

Pulse was measured at both ears of interactive operation users and passive observers for animation induction. The data were subject to chaos analysis to understand the impact of different speeds of movement in virtual space on the viewers.

Fig.7: Pulse Test at Both Ears (virtual reality system operation)

Pulse Test

(1) Testing Procedure

In the Victory Avenue project, we tested pulse of users (viewers) during operation of virtual reality. Users started from driving car and viewing from driver's point, then changed to walking in the railway station square and inspecting from pedestrian's point, and finally used flying through the railway station square and observing new buildings at the periphery of the square. Adjustments of landscapes were carried out at all three modes. We obtained the corresponding pulse data and performed chaos analysis.

(2) Experiment and Analysis

a. Chaos Analysis: In the testing, we use chaos analysis method to analyze the pulse data of the observers; we are going to demonstrate the method specifically.

Chaos means although some changes in some kind of system happen according to some determined rules, the changes are complicated, anomalous and unpredictable. The [determined rules] means the rules of the movement in some system are determined. In the process of movement, there is no flexible probability. If the initial data is determined at one point, the future situation is determined too according to some theories.

At present, chaos analysis theory is widely adopted in many sectors. There are two kinds of applicable methods roughly: the first is to extract chaos in the nature and analyze the chaos to predict the actual situation and changing trends of some phenomena. According to the kinds of method, a lot of phenomena which was deemed to be random are found to have chaos and it's possible to predict the trends of them. For example, weather forecast, stock analysis, earthquake scale and frequency, diction category, city population and city exponent and animal extermination, chaos is all around us. And it is applicable in human diseases prediction such as heart and encephalon diseases.

The second kind of chaos application is to extract chaos in simple regulations and use its abnormity as signals. It's more comfortable to use heater controlled by chaos signals. [1]Tahara [2] claimed:" Human body is chaos" in terms of either human or machine have nature of chaos. Human feel comfortable when the wavelength is matched.

As we talked in the previous paragraphs, there are many ways of using chaos. We do testing with the first kind of method which is to analyze the reports of finger pulse data of observers in VR.

b. Chaos Analysis of Ear Pulse Data

The principle of pulse test is determining pulse by capturing blood flow at peripheral capillary sequentially by near-infrared to measure hemoglobin reflection. The fingertip or the ear is often used for testing because blood vessels in these regions respond external environment sensitively.

Vital signs refer to information indicating the living state of human body. These include body temperature, blood pressure, and pulse, among others. Human body is of chaotic characteristics that cannot be determined by simple calculation. Vital signs detected from ear (fingertip and forehead) are different from electrocardiogram (ECG), as they reflect state of nervous systems as well. Therefore Lyapunov index calculated by complex non-linear analysis - chaos analysis following time sequence was employed.

As general knowledge in the future, it may be considered that a healthy body consists of movements of regular order, under inconstant conditions at any given point but recurring periodically. It therefore can be considered as one kind of fluctuation type mechanics process.

In other words, the living body resisting fluctuation is not avoiding changes outside but escaping cyclical chaotic fluctuation. It generates physiological and psychological compatibility and flexibility. Thus, chaos analysis with Lyapunov index is effective to analyze such non-linear data. Moreover, pattern of attractor, i.e. structure fluctuation (shape and pattern) and function, may indicate relaxation, concentration, brain activation, uncomfortable state, fatigue and other abnormal mental state as well as recovery, which are all signs of the activity of autonomic nervous system. The attractors of health, energetic state, concentration and sharp thinking are transformations of complex and dynamic total structures to complex partial ones by reversing to spiral-shaped forms, which can be compositions of more complex attractor.

Illness, abnormality and fatigue result in unstable psychiatric, psychological and physiological conditions. The attractor structure is converted into less complex, unstructured, linear configuration, leading to a mechanical periodic phenomenon, and consequently, composition of attractor reduces and the Lyapunov index decreases. In contrast, a person with healthy mental and physical condition maintains a dynamic balance with the environment, and his/her pulse attractor and Lyapunov index display an optimal sensible state of body and mind, represented as a unique status for the specific environment.

The chaos analysis of pulse data started with dynamics re-constitution. The parameters were set as follows: window length - 4,000 points, bury dimension - 4, delay time -10 o'clock. Lyapunov index was then calculated based on Sano-Sawada algorithm with the following mathematical formula.

$$\lambda_i = \lim_{t \to +\infty} \frac{1}{t} \log \frac{l_i(t)}{r(0)}$$

Here in the condition space, attractor is approximated to 2 (the distance is r (0)) based on the unstable track (divergence). Embarking from here, predication is made to estimate how far the two points will separate (information formation rate) along the two tracks (the distance is li (t)). Chaos theory indicates the greater the Lyapunov index, the more difficult the estimation. When Lyapunov index is negative, the tracks

tend to join together towards a periodic point. In reverse, positive index value suggests that two extremely close points embark on the track to separation with increasing distance.

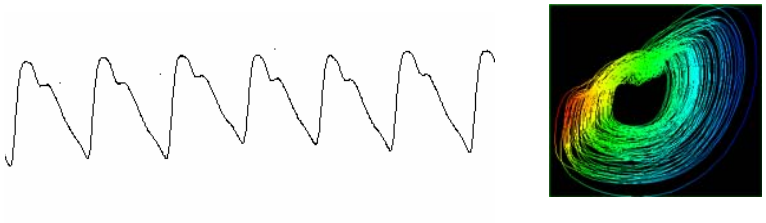

Fig.8: Plethysmogram and chaotic attractor

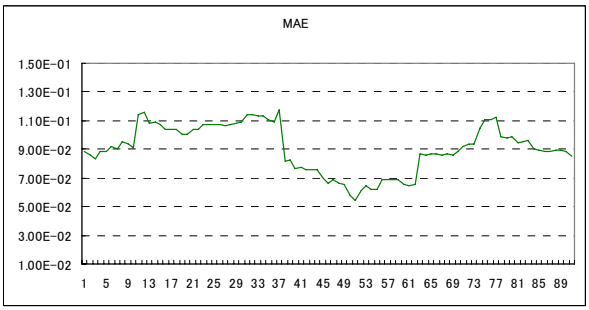

Fig.9: Temporal changes in largest Lyapunov exponents

(3) Result of Chaos Analysis

According to the above method, we analyzed the pulse data.

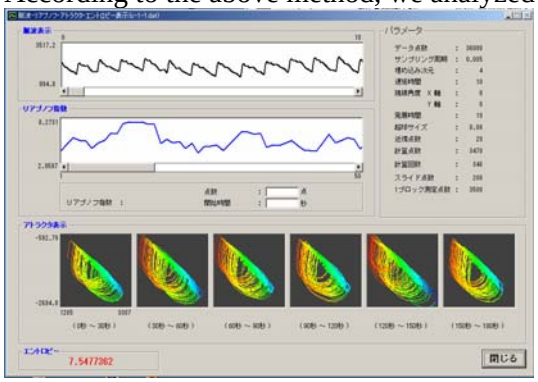

Fig.10: Result of Chaos Analysis

The results of chaos analysis showed that when the user observed passively the design represented by animation only, the attractor was rather flat, i.e. the fluctuation was compact. In contrast, game-like interactive operation of the user resulted in rich fluctuations, which indicated different states of brain activities. Moreover, when the user adjusted the height and position of buildings, each movement induced a spike reflecting excitement. This suggests that during the interactive operation, with the generation of a novel idea of design in the virtual space by the user/designer, his/her brain activation state alters accordingly.

4. Conclusions and Future Directions

Our study shows that pulse data are influenced by many factors, and chaos analysis may be used to provide certain insights into the brain activation and physiological conditions of human body. Further analysis of the results may shed more light on the factors influencing human conditions under various circumstances based on similar data.

Pulse test on both ears are employed in the present study and it is clear that the conditions on individual ones are different. It is possible that this difference is an indication of the different activation states of left and right hemisphere. We will carry out further analysis on this possibility to demonstrate the impact of operations by left and right hands on the brain. We will also collect EEG for additional analysis and compare with the results of pulse test to investigate what and how virtual reality technologies may assist mental activities and brain activation. And further applications and improvements of the virtual reality simulation will be expanded based on the outcomes. Inclusion of game-like functions will certainly result in additional intellectual stimulation, and further studies are needed to demonstrate convincingly the effectiveness of game-like functions in virtual reality urban planning and architectural design process.

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