# COGNITION RESEARCH BASED ON VGE: A CASE STUDY OF ENVIRONMENT AND HUMAN'S PERCEPTION

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**Abstract:** Since the rapid development of Virtual Geographic Environment (VGE), it has become an efficient tool for the research and analysis in cognition field. However, the research among human's perception is rare, especially for the purpose of urban planning or design. The method of transferring the environmental variables into human's feeling are not quite proper yet, for the data of air pollutants, most platform are only limited on the spread model and focus on the data display. Besides, the current research related with human's visual is mostly limited to 2-dimential situations, which lacks of a proper tool for 3D. The VGE platform could provide solutions for the 3-dimentional analyses of different data source, which could be a basement of the Multi-Channel Perception Model, for the collection of environmental sensible figures and building up the correlation with our human's feeling.

This research attempts to provide a possible VGE platform for the data access and integration related with multi-channel perception, and illustrate a measurable relationship between the environment and human's feeling. These may include the invisible environmental variables, such as noise or air pollutants, and human's visual, such as the feeling perceived from building groups. In this paper, all research and experiments are based on the platform of VGE, by using the software of Open Simulator. Two experiments are contained in this article, which are a simulation and visualization result for the distribution of CO (a type of air pollutants) in the Chinese University of Hong Kong (CUHK), and a correlation study between human's visual and spatial relationships.

## INTRODUCTION

Kevin Lynch has listed five basic elements for urban planning in 1981 (Lynch 1981), which include vitality, sense, fit, access and control. These elements supply a guide for urban design and relatively efficient value standards. In these five elements, "Sense" of urban space is described as the perception or mental structure received by urban users, and another word "fit" means the form and capability of urban space fit the behavior of human being. However, during current research the field related with human perception has been concerned not quite much, since it is thought to be difficult to deal with human's mental world. The research around human perception is considered hard to be measured or quantified, which restricts the analysis between the environment and human's perception.

Quantities of environment variables are invisible in the real world, such as the air pollutants or noise, but they are significant in the generation of human's feeling. High density of unhealthy air will cause uncomfortable and disease to human, even slight air pollutants will affect human's emotion. During current research, one of the main difficulties is to change these invisible data into "sensible" or "visible" through a possible technology. By the method of local observation the variables could be transferred to values, but they only represent for single point. While remote sensing technology could access the data value of an area by a single time, but the temporal continuity is not quite satisfied to the requirement. Several CFD models are used for the simulation of air quality data process, especially for the study of air pollutants distribution. The outputting data could be used for the visualization, such as in the platform of VGE. A VGE platform of air pollutants in Pearl River Delta area has suggested a good solution, which clearly shows the distribution of air pollutants data in a region area (Xu et al. 2010). In this platform the final users can query the pollutants in each specified location, and the temporal continuity keeps also well.

Furthermore, the visual perception of human is also thought to be a significant issue. All the human visual sense of urban spaces comes from our urban image, which is considered to be various from person to person. Human's

knowledge background and activity with urban space will generate and affect different sense from standard meaning (Montgomery, 1998). In the past there're not quite much psychological investigation related with metal images of geographic space, and all the efforts for psychologists mainly focus on the physics and physiology of the senses in laboratory work (Gould, 1973). However, around 1993 Dillon raised a navigation tool by using human cognition in urban area, which is a reasonable example for the combination of spatial perception and human behavior (Dillon 1993). Stamps III provides a possible way for the finding relationship between the enclosure of building groups and human's safety feeling in 2005, through the experiment of Law of Visual Permeability.

Both GIS and VGE plays an important role in recent spatial analysis area, especially the field related with urban control and management. In most situation GIS system is applied for the analysis of the road network accessibility and transportation management. Furthermore, the GIS platform has been used for the organization and management of quantities of spatial data in urban system. After the conception of VGE was raised, the platform of VGE provides an efficient tool for the data access, storing and management, and a friendly interface accepted by final users, which makes the whole output result more lively and comprehensive. Besides, the GIS or VGE platform related with humans cognition or behavior research has been developed recent years. A navigation model developed by Dillon in 1993 is based on the GIS platform associated with human's cognition towards the city, that is, by using human's background knowledge and human's image sense to provide the guide in a city (Dillon 1993). In recent ten years a few 3D platform has been introduced into VGE research, such as Open Simulator. A few researches have taken place on this platform, such as recording of avatar tracks to analyze their behavior, analysis around the spatial social behavior and private distance in virtual world, etc. (Kinicki and Claypoo1 2008), (Friedman et al. 2007). Because of this, in this research we want to integrate the model dealing with human's perception data together, and build up a possible platform for the Multi-channel Perception Model. In this VGE platform, the relationship between environment and human's perception will be focused, including the method of data acquisition, management and visualization.

## METHODS

VGE is not the technology the same with 3D GIS, although both of them are dealing with 3D environment models and spatial relationship. VGE is more alike a platform with data interface, which can be accessed by other software. By input the data into VGE, the function of data storing, management, analysis and visualization will be realized in this platform. The software of Open Simulator (OpenSim for short) will be adopted as the platform of VGE in this experiment. As OpenSim is Internet-based technology and multi-user accessible, it has two clients for both server and customer. From the following graph we can see the detail of its inner structure. The physical environment data is storing in the database of the grid, which is inside the server part. By passing the data through the Internet to the browser, the customer part will do the visualization for the 3D environment and provide the alive and vivid picture to the final user. Besides, through the Internet other data could be supplied to the browser for the final visualization, such as the data dealt by CFD models for pollutants simulation.

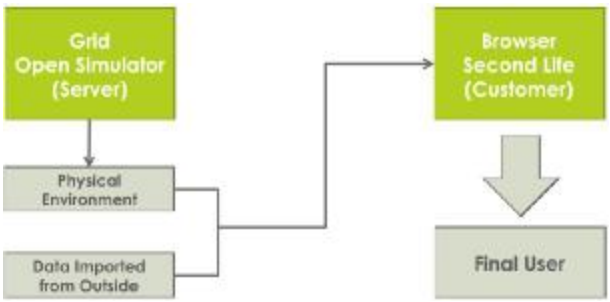


**Figure 1:** Inner Structure and Work Flowing Chart of OpenSim VGE Platform

To process the cognition research based on VGE, a structure of Multi-channel Perception Model must be designed based on the idea of multi-sensor network, process model and participation of human. In this model, two main parts are included in charge of different functions. One is the dynamic process model for the collection, analysis and visualization of invisible environmental variables, and the other one is the visual correlation model for dealing with spatial relationship and visual perception. They are both based on the same platform of VGE (OpenSim as the main software), and integrated as the reason of their common focus on the process of cognition.

The source of input data could be various in this Multi-channel Perception Model. For environmental variables in dynamic process model, the principle income of data is from different types of sensor network, such as the sensor for observing air pollutants and noise data. Video camera could be another source of data input, since it is an

efficient tool for recording the real-time environment situation and human's activity. Simulation result from other software will also be available. For the visual correlation model, the main data source is coming from spatial information extraction work based on geographical models. In our experiment, the models of whole CUHK campus have been finished inside the VGE platform, including the details of topography (derived from 1m precision DEM), buildings, furniture and vegetation. Because of this, the data source is precise enough for the generation of spatial relationship between buildings.

The platform of VGE (take OpenSim for instance) is a place not only for providing the data source but also for the integration of all input data. As OpenSim, the software supported our VGE platform, is based on the database of MySQL, the data obtained from other sources could be stored inside for management. Besides, it provides a convenient method for data query or visualization through the graphic engine of OpenGL, because the data format is standardized and supported by the software of OpenSim, a C++ based program.

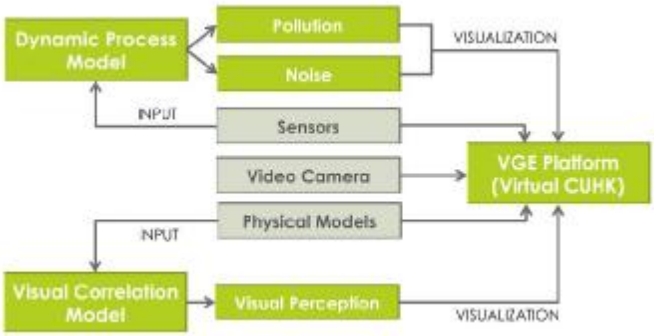


**Figure 2:** A Structure of Multi-Channel Perception Model Based on VGE Platform

**1. Dynamic Process Model**

The dynamic process model is for the simulation of the continuous geographical process in a certain period. In this experiment, we mainly discuss about the data input method and its visualization. The data source could be various as introduced, such as sensors, video cameras, observation data from the Internet or preprocessed data output from other software. The sensor data as a principle source are significant, since the location of sensors could be arranged by ourselves, which is useful for us to obtain the accurate data in specified area. While the sensors data is only for the representation of single or multi points, a CFD (Computational Fluid Dynamics) model is required for the distribution of data in whole campus area. With the data from sensors and preprocessed by CFD, the VGE platform will complete the visualization work in the final step, and provides the result with the interface to the final user.

As the type of data source is various in this VGE platform, the visualization method will be different from each other. For example, the visualization of video camera is more alike a video inside the virtual world, which simultaneously shows the real world situation. For the distribution of air pollutants or noise, the method of drawing points or polygons is mostly common used, as the density could directly implied via different colors. Besides, as the VGE of OpenSim is avatar based virtual world, by controlling the avatar, the query of surrounding pollutants density could be realized in this platform. The query result could be directly shown on the screen, which makes the dynamic process model more vivid and believable.

**2. Visual Correlation Model**

According to the definition of human's cognition towards an existed space by Kevin Lynch, that is a person who is getting familiar with the space must pass through 3 levels, they are identity representing for the profile of object, the structure for storing about the location and scale, and meaning (Lynch 1960). Because of this, the visual correlation model here will contain three data layer, which are the spatial layer, for acquisition and management of the models' spatial information; sematic layer, for storing the identity of different objects; and the conscious layer, for computing of the human's reaction towards different types of spatial combinations. The relationship between each layer could be explained as following figure, and the visual correlation model is defined as the one dealing with the relationship between spatial information and human's perception. All these structure are intergrade by the software of Open Simulator, with sharing the MySQL database for their data management.

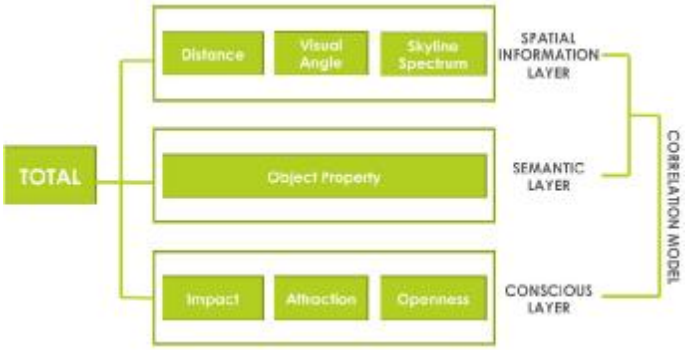


**Figure 3:** Data layer structure for the Visual Correlation Model

In this experiment, the spatial relationship extraction methods are considered to be the key issue for the whole visual correlation model. Those will include three parts, distance, visual angle and visual field (skyline for instance). For the definition of distance, it means the 3D distance from the observer towards a target object. The visual angle is defined as the horizontal and vertical one, which can be restricted within a rectangular facing the observer. If we do the calculation of surrounding objects for observer in all directions (360 degree), and arrange all the data together, we can get the definition of visual field, a series of visual angle in all directions. It can also be noticed as the skyline spectrum for the surrounding objects. These mathematical relationships would be closely related with human's visual perception, such as the feeling of crowd, order, continuous or even emotional feelings as comfortable and harmonious.

## EXPERIMENTS AND RESULTS

Two experiments will be introduced here, one is related with the dynamic process model, with the management and visualization of invisible environmental variables (take CO for instance); another is an experiment about the correlation between space and human's visual, which is related with the visual correlation model just mentioned.

### 1. Invisible Environmental Variables

Although the environmental variables such as air pollutants, noise, temperature, humidity, etc. are invisible, the collection and visualization could be done through the platform of VGE. The whole experiment is based on the software of Open Simulator, using for the simulation and visualization of air pollutants distribution inside CUHK campus. A sensor network is used for the acquisition of pollutants data, such as for the source of noise and CO. Besides, pollutants source data provided by Hong Kong Observatory are also considered in the whole experiment. As most accessed data only represents for the density of single point, a model of CFD (Computational Fluid Dynamics, software of FLUENT for this experiment) is used for the simulation of pollutants distribution in a wide area.

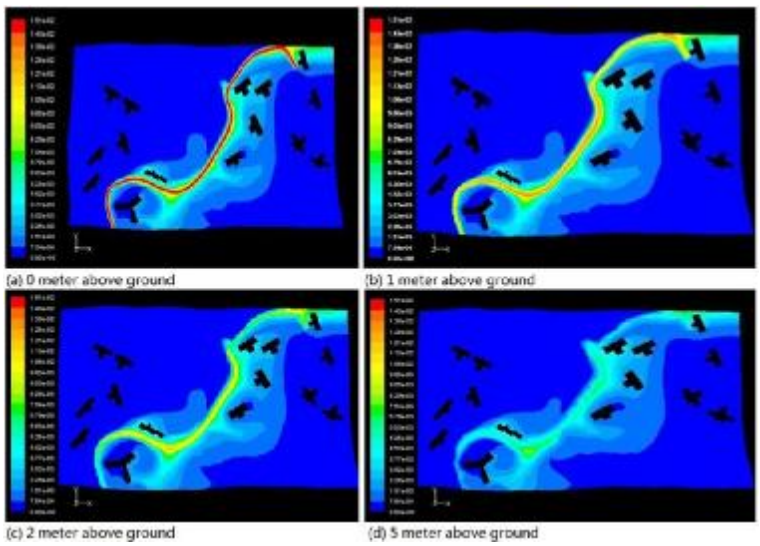


**Figure 4:** Expression of traffic pollutant source (road) and mass fraction of CO in CFD (wind flow is from west to east)

The data source could be output from FLUENT, after the simulating calculation of CO spread in the whole campus. Each data will be marked with the 3-dimentional coordinates and the attribute value of CO density. The data classification is indexed by the elevation from the ground surface. In this experiment, the CO density value is gathered together every 16 meters above ground, and output into a separated text file. Finally, the visualization is completed in the software of Open Simulator.

The OpenGL, which is the graphics engine inside Open Simulator, will realize the whole visualization process. As the coordinates output from FLUENTS are based on the grid of Hong Kong Grid 1980, which cannot adopt with the grid system of Open Simulator, a simple transfer of coordinates is necessary to solve the problem. Since the regions of OpenSim are highly restricted into 256m * 256m, the visualization of pollutants needs to be divided according to the boundary of different region inside OpenSim. In this experiment the represents of air pollutants are using the method of "draw-point", and the color will be changed according to is current density. Air pollutants data could be imported into OpenSim and display by layers, since the data source is organized by the elevation of every 16 meters. The following figure shows the visualization results in part of Virtual CUHK campus. From the figure we can clearly notice that, the CO density is higher near the main transportation roads and descending by the distance.

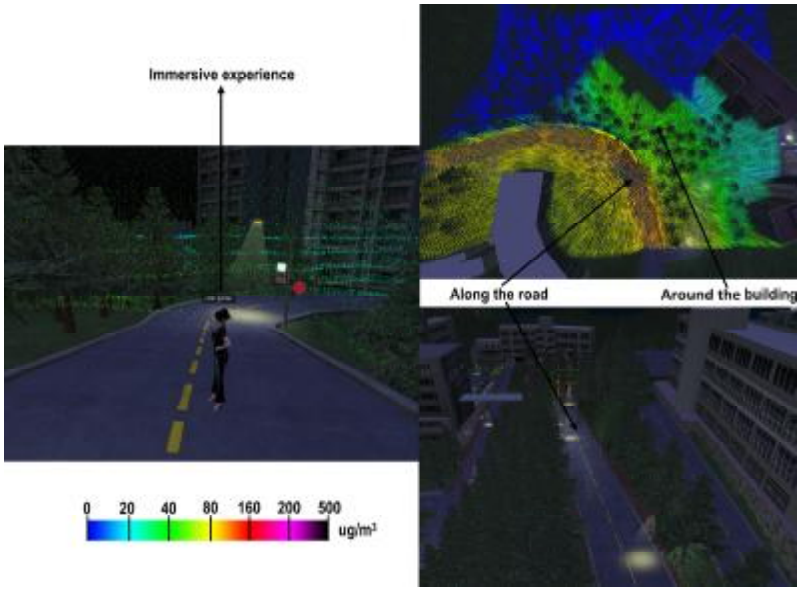


**Figure 5:** Visualization of Air Pollutants Data (CO) based on Open Simulator

As OpenSim has an avatar-based browser for 3D environment exploration (Second Life Viewer are used in this experiment), avatar plays a significant role in our VGE experiment. An example shows that by manipulating the avatar inside and using a plug-in algorithm, the query of surrounding pollutants density could be available. The 3D coordinates of avatar could be derived by OpenSim once the avatar shifts his location, and buffer analysis of air pollutants is applied simultaneously when the position is changed. By a simple query from the database, the surrounding pollutants value could be figured out, such as for the distribution of CO in CUHK campus (See Figure 5). The result is displayed surrounding the avatar or along the trail, which implies the attributes of air pollutants that the avatar has suffered just now.

## 2. Human's Visual Perception

As the first experiment only solved the problem of environmental variables, another experiment is necessary to validate the possibility of human's visual perception model. The same with former one, this experiment is based on the VGE platform of Open Simulator, with full 3D physical models of whole CUHK campus. There would be two main questions needing to be concern about, one is the extraction of spatial information between each building models, the other one is the collection of human's feeling from real world. The latter one will be realized through a systematic questionnaire investigation inside CUHK campus, for collecting the environment feed back from students or staffs.

### 2.1. Extraction of Spatial Information

The extraction work is mainly done by the VGE platform of Open Simulator, the same with first experiment. As the 3D campus models has already completed with enough details inside, there is no difficulties for the calculation of

spatial relationship between each buildings, or between buildings and observer (avatar controlled). Three figures are considered to be the key issue of spatial information, and they are: ***distance, visual angle*** and ***visual field***, which have been mentioned in the method part of this article.

The first figure distance is thought to be the key issue, which affects the perception of target objects received by observer. The generation of distance detecting in human's mind is from the two eyes system, since there could be slightly visual direction difference between the images percept by the two eyes. Different distance will affect the variance in visual perception, such as the change of openness and intimacy. During the research result of Bittermann and Ciftcioglu 2006, the relationship between distance of noticing flat object and openness perception is represented by the sigmoid function

$$f(x) = \frac{1}{1+\exp[-(x-x_0)]}$$

, $x_0$ is the closest distance between a flat object and observer. However, not all the objects in the real world are flat. Considering about the principles of distance generation in human's visual system, the distance shows another relationship with human's perception rather than the sigmoid one. Suppose the rotation difficulty is equal in all directions for our eyes, we can conclude that the visual impact relationship with the distance should be expressed as following

$$f(x) = k \cdot \arctan\frac{w}{2x}$$

, both k and w is constant, and x is the distance. Whether the correlation model between distance and human's visual impact is the first type or the second one is still not clear, and the field survey designed for the correlation model construction will do the validation of these two functions. The distance between the observer and target could be figure out through OpenSim. With the known coordinates of the observer and object location, the platform get the distance from the distance equation between two point in this 3D coordinates system. The distance data obtained will be marked with the building ID and stored in the database for further analysis.

The visual angle is also thought to be an important issue affecting human's feeling, especially deciding the visual impact of the target. Normally it is thought that larger visual angle object is easily noticed by human, and has larger visual impact effect against the observer. While the relationship between the visual angle and visual impact is not quite clear. Supposed the influence of distance is not considered here, the visual impact f(x) shows proportional to the visual angle α. The measurement of the visual angle inside a 3D environment is difficult, because nearly all the objects show an irregular visual angle in our eyes. To simplify the definition of visual angle and make it measurable, I use the idea of horizontal and vertical visual angle to solve the problem. In this OpenSim VGE platform, we can extract the coordinates of the object out and get the extreme value among each vertex, such as the maximum and minimum spatial vector in both direction. Then the horizontal and vertical visual angle can be got from the angle of the maximum and minimum vector. An automatically fetching visual angle program has been plugged into OpenSim, which can compute the visual angle for all the objects immediately. The data will be storing into the MySQL database for further analysis, such as the validation experiment designed in future.

**Figure 6:** *Left:* Meaning of visual angle (vertical); *Right:* Extraction method of visual angle in OpenSim, by using the method of bounding box, and calculate the visual angle for a box in horizontal and vertical direction.

The last figure of visual field can be explained as the combination of a set of visual perception values for a certain location observer. It is recognized as an export factor from the value of visual angle, to make connection with the generation process of human's perception. It could be represented by the method of spectrum marking the actual visual angle value for each separate degree, which indicates the skyline and horizon of the surrounding environment. This spectrum of visual field can provide a tool for the understanding of image in our visual perception. For the data simplifying only the border of visual objects will be considered in this visual field, that is the skyline of a certain location. Different visual field pattern will imply different spatial pattern. For the pattern

like square, the visual angle surrounding by the observer should be more or less the same and limited in the range of a certain value. For courtyard type, the visual angle value is larger, but also controllable. While for street the boundary visual angle should increase sharply. Because of this, the skyline spectrum shows different pattern with each other but similar with the same urban pattern places. We can know the identity of the urban space through the spectrum discipline, that's what we need to extract from the various spectrum pattern.

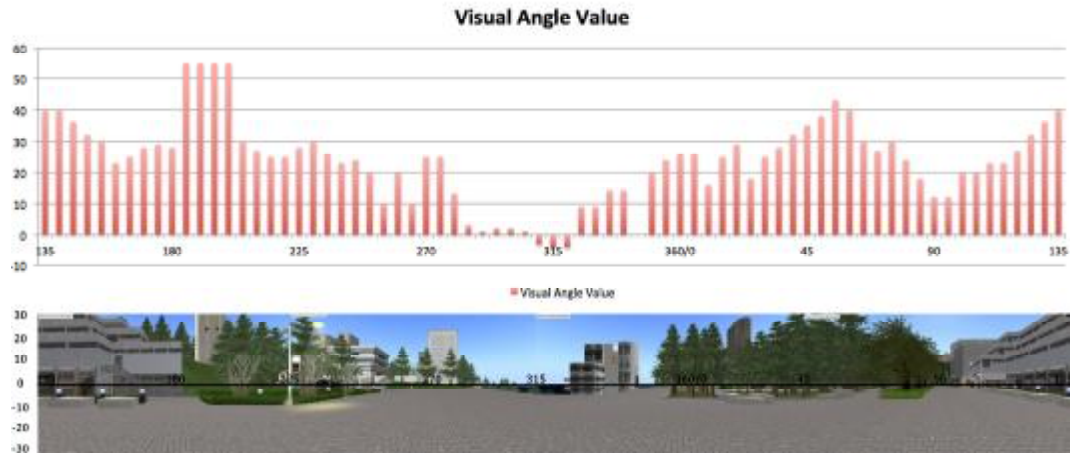


**Figure 7**: *Upper:* Simulation Result of Visual Field of United College Square, Virtual CUHK; *Lower:* A Full 360-degree View of United College Square, Virtual CUHK; The Gage of Visual Angle is marked to the Left.

### 2.2. Acquisition of Human's Perception

Two field surveys are designed for the acquisition of human's perception inside CUHK campus, one location is in Central Campus Square and the other in Lotus Pond of Chung Chi College. The method of questionnaire will be adopted for the information collection. The participants will cover the students and staffs of CUHK and the number of samples requires around 150 to 200. As visual perception is a type of common feelings of human, the differences between individual are ignored in this research.

Similar with the research method of Lynch in 1960, 3 main sections are covered in the questionnaire design. The whole survey is more alike an interview rather than a questionnaire, because more participation is arranged according to the situation. The first part is an ***evaluation table***. In this section participants are required to give their evaluation for each single description. These may include the description about space, such as wideness, crowd, order and continuity; description about color and sound; description about emotional feeling, such as beauty, attraction, enjoyment, comfort, etc. 20 couples of description words will be contained in total. For the second part, there will be a ***rank test of single building / target object*** according to 5 standards, which are ***visual impact, attraction, significance, curiosity*** and ***preference***. The rank order will decide the weight got by each target object, and finally generates a statistics table for these 5 standards. The last section is that, every participant is required to ***take a photo at a specified location***, but the direction towards could be judged by him or herself. This will test the preferred direction and scenery content for each single person. Through the method of content analysis, useful information could be extracted such as the preference rank among each building, which is also related with the spatial relationship mentioned above. Besides, the background of each participant will be collected in this field survey, such as age, gender and basic knowledge of CUHK campus.

## CONCLUSIONS & RECOMMENDATIONS

The whole research provides us a Multi-Channel Perception Model for the integration between environment and human's perception, which is based on the platform of VGE. During this OpenSim based VGE platform, the 3D virtualized geographical model are accessible. With the support of dynamic process model and visual correlation model, the application of this platform has been widened. Besides, there will more possibility if the access of other models could be applicable. The VGE platform will also become a platform of various accessible data, and apply for the data access, management, and visualization.

For the dynamic process model, it provides us an efficient tool for the integration of geographical process with 3D virtual world. By the input of invisible environmental variables, the 3D distribution of these figures could be stored and displayed in VGE, which can be queried or visualized by the final users. The access of outside software is also available, if data the format has been unified to standard.

For the visual correlation model, it is an attempt to do the correlation study between human's perception and spatial relationships in the environment, since there's few research concerning about the generation or correlation of human's perception. Three types of spatial figure are considered in this model, and they are distance, visual angle and visual field. These changing figure will affect human's perception in visual and emotional feelings, which will be validated in the future progress of this research. As the experiment of visual correlation model hasn't been completed, the further work of this research is to finish the collection of human's perception and build the correlation model between perception and spatial relationship.

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