32

The Three-Dimensional User Interface

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1. Introduction

This chapter introduced the three-dimensional user interface (3D UI). With the emergence of Virtual Environment (VE), augmented reality, pervasive computing, and other "desktop disengage" technology, 3D UI is constantly exploiting an important area. However, for most users, the 3D UI based on desktop is still a part that can not be ignored. This chapter interprets what is 3D UI, the importance of 3D UI and analyses some 3D UI application. At the same time, according to human-computer interaction strategy and research methods and conclusions of WIMP, it focus on desktop 3D UI, sums up some design principles of 3D UI.
From the principle of spatial perception of people, spatial cognition, this chapter explained the depth clues and other theoretical knowledge, and introduced Hierarchical Semantic model of “UE”, Scenario-based User Behavior Model and Screen Layout for Information Minimization which can instruct the design and development of 3D UI.
This chapter focuses on basic elements of 3D Interaction Behavior: Manipulation, Navigation, and System Control. It described in 3D UI, how to use manipulate the virtual objects effectively by using Manipulation which is the most fundamental task, how to reduce the user's cognitive load and enhance the user's space knowledge in use of exploration technology by using navigation, and how to issue an order and how to request the system for the implementation of a specific function and how to change the system status or change the interactive pattern by using System Control.
Finally through the case analysis, it highlighted the experience and interactive of 3D UI. And then it analyzed elements affecting 3D UI interactive mode from the Psychology, interactive design and information show.
3D UI has come to the transition time from the technology-driven to the design-driven. This section gives the readers a basic understanding of 3D UI. It focuses on the basic concepts, advantages and limitations between different latitude UI, its applications and the studying contents.

1.1 Concept of 3D UI

1.1.1 Definition of 3D UI

With the development of computer hardware and software technology and the increased demand of application, digital terminal equipment diversification, such as cell phones, PDA (Pocket PC) terminals spread, and so on, that the time of Pervasive Computing has arrived.

Currently the shortcomings of the WIMP interface occupying the mainstream position are also increasingly reflected.
From a technical perspective, WIMP interface used "desktop" metaphor which restricted the human-computer interaction; imbalance of computer input/output bandwidth; complex operation grammar and the small-screen effect; used the ordinal dialogue mode; only supported precise and discrete input; can not handle simultaneous operation; can not use the auditory and tactile; all of these make it clear that WIMP interface is unable to adapt to pervasive computing.
Since the 1990s, researchers proposed the idea of next-generation user interface. As one of the main forms of interface, three-dimensional user interface is attaches importance for its natural, intuitive features. The increase of the dimensions brings about a qualitative change to the user interface, as shown in Fig. 1.

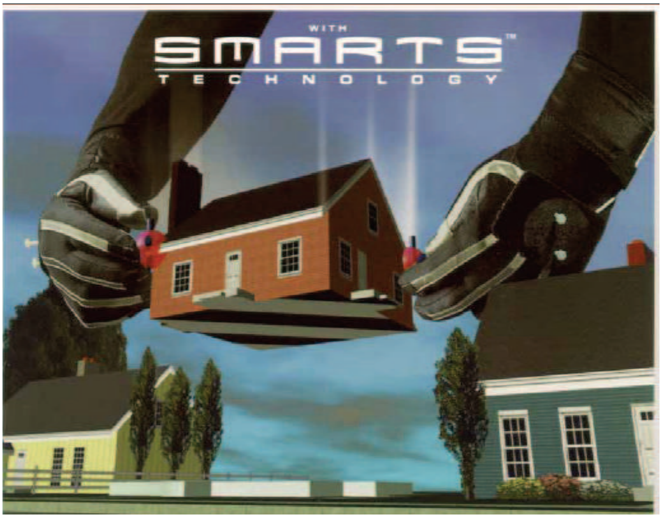


Figure 1. 3D UI

User interface can transform the user's behavior and state into an expression that computer can understand and operate, and then transform the computer's behavior and state into an expression a user can understand and operation. The three-dimensional user interface is a human-computer interaction that users can directly carry out the tasks in the 3D space. Its visual angle is like a free camera angle lens, which users can self-control the direction of visual angle.
3D virtual environment is a new human-computer interaction, using this mode the user can enter to a cyber space that virtually unlimited, and interacting with inner objects in a natural harmony way. This cyber space can describe things existing in the real world (that is, "real things to virtual"). It can also describe the things that entirely imaged or things that existing in the real word but people can not touch (that is, "virtual things to real"). It may also known as virtual reality environment.
3D virtual environment system has three features which are Immersion, Interaction and Involvement, which is called 3I characteristics.

The current 3D virtual environment system included: Desktop, Half-physical, Visual Immersion, Augment Reality, and Distributed Virtual Environment, in Fig. 2. Shown.

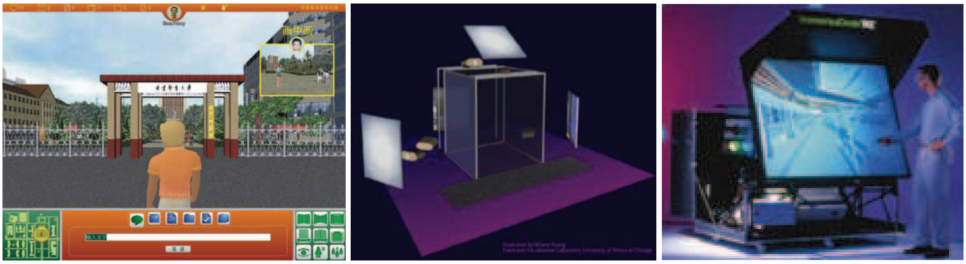


Figure 2. 3D Virtual Environments

These systems not only need the technology of viewpoint transform, but also need the system control technology of choice, move, rotate of objects. These systems can not become a mainstream application because of the immature of peripheral hardware, the naturalness of interactive technology and lower usability of these systems. The three-dimensional user interface under the desktop environment is more mature.

1.1.2 Advantages and disadvantages of 3D UI

3D UI does not replace the traditional 2D graphical user interface paradigm, but solves the poor performance of the traditional mode in interaction. Compared with the 2D interface its advantages are as follows:

- Scenario context

3D scenario enhanced the users' comprehensive capabilities of dealing with information, including awareness, perception, learning and memory.

- Information architecture and layout

3D UI provides a new space for the organizing, bearing, showing a more complex information. More importantly, with the trend of the high-capacity and high complexity of the future industrial information platform, there is an urgent need for a new interface presentation, which can not only carry information, can also performance the relationships and differences between different types of information. 3D UI shows great potential in this area.

- Information visualization

3D information visualization makes information shows more directly and more easily to understanding. In essence, graphics and representation can make the users easier to understand and identify the information.

- Interaction Experience

On one hand, 3D interaction can introduce many more natural and rich actions in the real world to traditional human-computer interaction; On the other hand it can show a more attractive new interactive way through breaking the world restrictions.

However, 3D UI also has some own shortcomings which is inevitable, such as got lost in a complex map in the 3D scenario which can bring disorientation, spending more time to learn the navigation, slow study being the cost of rich visual experience, and s unable to get the users' desired view.

- Offer new different structures

3D seems to provide the possibility for representing many dimensions of information and meta-information in a compact way and various structure (3D Navigation).

- Do something which 2D couldn't realize

3D structure / environment are helpful for certain tasks. So we have to explore the best place 3D used in.

3D UI's characteristics inherent present us with new challenges. So far, there has not been summed up a 3D fixed interface paradigm similar to WIMP. On the other hand, 3D UI related to many other subjects such as cognitive psychology, human-computer ergonomics, and so on. And the study of perception and psychological mechanism of processing is not yet mature which also limits the 3D UI research in a certain extent. Although we are living in a three-dimensional space, but in reality the rich three-dimensional objects clues such as the space layout, the human feelings, physical restraint and so on, have not been a unified expression. The existence of these problems gives many challenges to 3D UI research.

1.2 The Content of 3D UI Research

1.2.1 Related Research Fields of 3D UI

3D user interface related to cognitive psychology, human-computer ergonomics, and other disciplines of study. But the research of the perception and mechanism of psychological processing is not yet ripe, and it limited the 3D user interface research to some extent. Although we are living in a three-dimensional space, but the rich three-dimensional cues in reality, such as the objects space layout, the human body feelings, physical restraint and so on, do not have a unified expression.

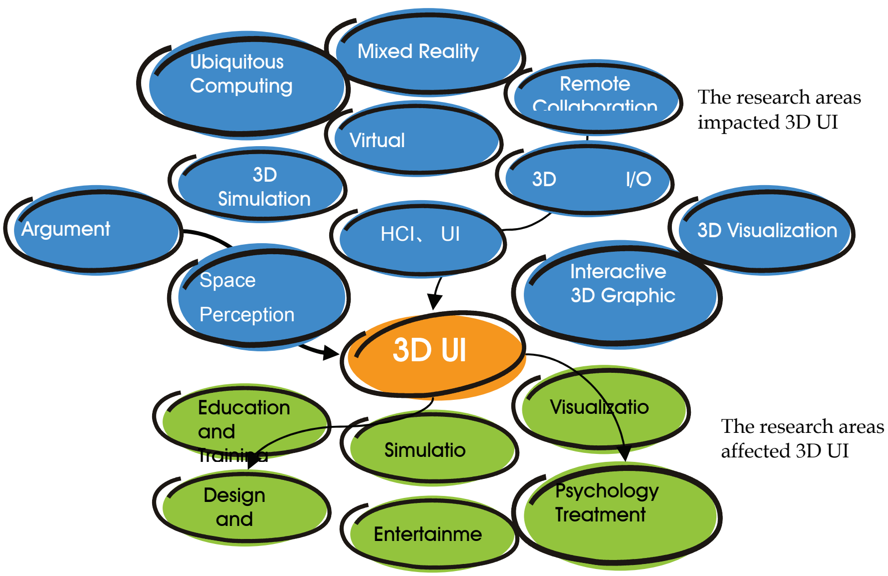


Figure 3. Related Research Fields of 3D UI

3D user interface is an intersecting research area related to multi-disciplinary, it is impacted by many research area, such as space perception, cognitive psychology. And at the same time, it also affected many research areas, such as information visualization, entertainment and education training, etc. The relationship between these parts and the related research areas can be shown by Fig. 3:

1.2.2 The content of 3D UI

3D UI can be studied from two aspects: Technology Elements of 3D UI and Design Elements of 3D UI.

(1) Technology Elements of 3D UI include: Human Factor, 3D Interaction Technique and 3D I/O Device. As shown in Fig. 4:

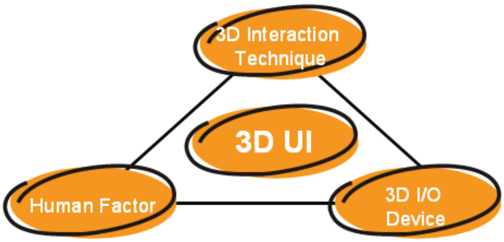


Figure 4. Technology Elements of 3D UI

Human factor mainly studied on visual perception and 3D depth cues, human spatial capabilities and the differences of individual ability, structure spatial knowledge of 3D environment, sound perception of space, manually picking and dragging characteristics, behavior cognitive planning, on-site and other aspects. Among all aspects above, on-site is a phenomenon which has been done a large number of exploration but not yet understand entirely, it was assumed that has a certain effect to the space knowledge. This means that the stronger on-site users were feeling in the virtual world, the more effective his search path done. Many factors affect the on-site feeling, such as the sense of immersion.

3D Interaction Technique mainly researched on navigation, selection and operation, system control. The navigation is mostly about on physical movement technology, driving skills, path planning, and the technology based on the destination, spatial knowledge, procedural knowledge, global knowledge, user-centered path searching and environment centered path searching. Selection and operation researched on pointing technology, virtual hand, world miniaturize technology, 3D desktop operation technique. System Control mainly include the adjusted 2D menu, 1 DOF menu, TULIP menu and 3D Widgets.

Input devices include the mechanical input devices, electronic input devices, optical input devices, voice input devices, inertial input devices and omnibus input devices. It has six aspects of usability problems: speed, accuracy, ease of learning, fatigue, cooperation, sustained and obtained of devices. Output devices include visual output devices, image output devices and mixed-output devices.

□2□Design Elements of 3D UI include 3D Scenario, 3D Widget and Interaction Devices. As shown in Fig. 5:

Relative with the traditional 2D system, 3D interface use its own three-dimensional scenes, it allows the users live in a shared virtual environment by the incarnation, it provides users the channels to understanding others, communicating and cooperating with them, and provides a context environment with different type of sharing object. 3D Widget is a conception extended meaning from 2D graphical user interface, similar to the button and icon in WIMP, the main purpose is to assist users finish complex tasks with low degree of freedom devices, user will be able to transform objects freely by indirect operating widget using mouse. 3D Widget is frequently used to data accessing of entity, such as zoom, rotate, stretch, and so on. Since the degree of freedom of one Widget is limited, so it also was known as limited manipulation technology. Excessive use of widget will occupy the screen space, and require users to remember the mapping relationship of each Widget at the same time, so it is commonly used in desktop environment of 3D interaction.

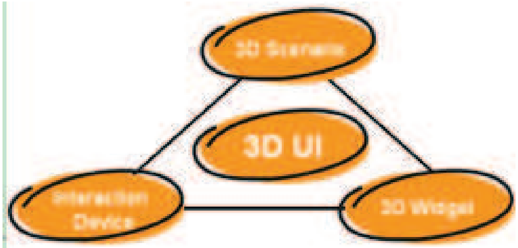


Figure 5. Design Elements of 3D UI

1.3 Application of 3D UI

Along with the improvement advance and falling price of hardware, the demand of application is increased, 3D UI gradually penetrate into lots areas of application. From the beginning of the data browsing to the interactive design, from the massive information visualization to the immersive entertainment, from military to civil parts, the extension and maturity of an increasing number of application system makes people aware the superiority and huge market potential of 3D interface. Overall, we can divide the application to several areas followed: simulation shows, real-world metaphors and 2.5D UI adapted from 2D.

(1) Simulation Shows

Figure 6. Simulation Shows

As shown in Fig. 6, the simulation shows have a typical application in simulation systems, PC games such as Sims™, prototype construction, etc. The main feature is that users have been known how to use the interface from their Day-to-day experience of life, so the time spend on interface learning is the least.
In the field of product design, the use of simulation shows is able to let the multi-designer self participate in the product design process, carry on the virtual assembly and virtual test, so it can save both time and costs.
The goal of simulation shows is to promote the intercommunions and cooperative works. Through the intercommunion, can promote the work flow, personnel arrangement, resource information optimization; provide more natural and interesting operant behavior.

(2) Real-World Metaphors

The use of real-world metaphors is shown in Fig. 7. The typical application of this area is 3D desktop management system, its main feature is that the whole area of human activity can inspire and guide the design of 3D UI.
For example, the construction and the virtual world are based on the shape and style of the arranged and organized space, thus the principles of architectural design can be transferred to the 3D UI designing. In some 3D desktop management system, some elements of architectural are used, such as the wall, desktop, they allowed users to obtain the operation knowledge quickly.
Metaphor is just a starting point, the interactive technique based on metaphor must be designed carefully, to match the application demand and the restriction of the interactive techniques.

Figure 7. Real-World Metaphors

(3) 2.5D UI

2.5 D has a typical application in real-time strategy games, as shown in Fig. 8. The main feature is that the well mode of interactive had been established in 2D interface, can make the 3D interface design easier to find suitable interactive technology; learning process can also become the shortest. The interactive in 2D is obviously easier than in 3D, users just have to operate 2 degree of freedom but not 6, so 2D interactive can let users carry on some tasks with a higher accuracy (such as selection, operation).
We can apprehend the 2.5D UI as a limited 3D UI, the interface objects is three-dimensional, but they all “grow” on one plane. 2.5D user interface is a transitional stage between 2D GUI and 3D UI, it is an imitated 3D interface display mode, appeared with the progress of the game three-dimensional technique. The visual angle is no longer the overlook or side-view as traditional 2D view, but fixed the user’s perspective at a certain angle in the air (it’s usually the

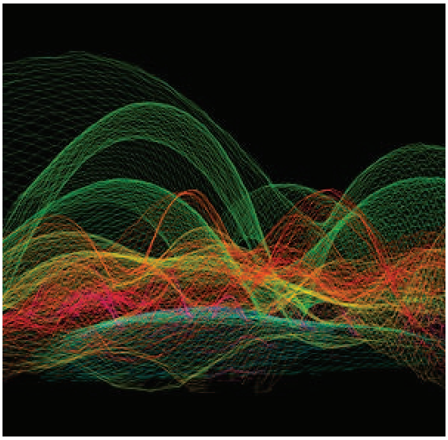
axonometric view), so it can present a virtual 3D effect. But this is only a visual on 3D, because our visual angle fixed at the certain angle, so we can just move on a plane or zoom the view range, but never see the other sides of these object on the screen. It is just like you paint a jar on canvas, but no matter it looks like a true one, you will never see the back of this jar.

Figure 8. 2.5D

2.5D UI at such a preceding position connects link 2D and 3D, it put forward an innovative integration strategy on all levels of cognitive perspective, interactive and information expression.

(4) Developing visualization information

Today there are various sophisticated methods to locate sound, but known visualizations still strongly remind of thermographic images. Acoustic shapes, unlike thermographic ones, differ from the contour of the measured object. Image overlays make it even more difficult to read and compare the results. The diploma thesis "Digital Acoustic Cartography" is an interactive experiment in mapping sonic events into a concrete visual language. Source material for the visualizations are image sequences recorded by the "acoustic camera", developed by GFaI, Berlin. Both, acoustic and photographic images are analyzed by processing. The color spectrum of the acoustic images is used as distortion matrix to warp the original picture into a three-dimensional relief. The color code is replaced by the photographic data.



NaturalHazards.info is an information-graphic elaboration of the topic of natural disasters – a java-applet. Here, place markers (cubes) of great natural disasters are arranged in space according to geographic and temporal location. They can change in colour and size according to their figures. The user can navigate in space freely, head for individual cubes and continents and get textual information. Further functions include an individual filter as well as a map of the world which can be moved in time. The result is a readable reflection of the facts changeable interactively.

2. Theories and Principles of 3D UI Design

This section explained some theoretical knowledge such as the depth cues, and reaction time, dynamic Vision domain based on the principle of the space perception, spatial cognition and behavior. And it also introduced design concept of "Bottom—Up User Experience", and scenario-based user behavior model—GSOME. Eventually we conclude valuable principles and guidelines about screen layout, navigation, selection, feedback and etc. All of this will guide the design of 3D UI systems.

2.1 Introduction

Any of 3D UI needs export information to users through output devices. They provided information to use's one or more sensory organ through the user's perceptual system. Most of these were used to stimulate vision, auditory and tactile; a few can stimulate the sense of smell and taste. This part mainly mentioned the devices based on the Vision. How can the computer's digital content change into the information that users can understand? It mainly depends on the perception of the human eyes. Understanding of three-dimensional imaging in the human eye and static/dynamic visual characteristics contributes to the 3D UI design.

2.1.1 Depth cues

Users need to understand the structure of 3D UI scenario, particularly the visual depth. Depth information can help users interact with 3D applications, in particular to manipulation, navigation and system control in 3D system. The visual system extracts 3D information using many depth cues provided by visual devices.

Three-dimensional visual is the three-dimensional sense when observated objects, that is, the human eye has the depth perception ability of the objects. The perception about the distance and depth is called depth perception, also known as distance perception. It includes absolute distance (the distance between observers and objects) and relative distance (the distance between two objects or the distance between different parts of one object). It is very important for judging the spatial relationships between objects. Perception depth comes from the external environment extracted from the human eye and depth of the many Depth Cues extracted from internal body. In the visual, these cues can be divided into monocular and binocular clues cues.

(1) Monocular Cues

Monocular cues are the cues that are provided by only one eye. Monocular cues are mainly static, such as the environment and the physical characteristics or phenomena of objects. It also included some sportive cues of one eye. In painting, the pictures can show 3D stereo effect in the two-dimensional plane by using of static monocular cues. So Monocular Cues is also known as graphic cues.

Monocular static cues include:

Size. If the distances between the user and the objects are different, it will form different size images on the retina.

Obscured. If an object is obscured by another object, the obscuring object looks near to us, the other one looks far more.

Perspective. There are two objects having the same size. The perspective on the proportion of the object which is near to us is large, the video also big; vice versa. In railways you can see that, the two tracks near the distance between the two rails near to us are broad, far narrower.

Air Perspective. As the effect of blue-grey color air, when we look at distant objects, we will feel that, the more far from us, the less details we can see, such as more blurred and the color more light. The disintegration phenomena that appear in details, shape and color is known as the air perspective. According to such cues people can also guess the distance between the object and us.

Light and Shadow. We live in a world of light and shadow. Darkness and shadow look more far from us; but bright and high-light part look near to us. In the arts of painting, the part far from us uses dark colors, and the part near to us uses vivid color. This method can create the sense of distance and three-dimensional effect.

Relatively High. If other conditions are equal, the object relatively higher looks far more.

Texture Gradient. It means the projection size and projection density of the objects in the retina change orderly. According to texture gradient in the retina change, the small and dense objects are far from us, and large and infrequent objects are relatively close.

Monocular Movement-Produced cues:

When the observers have a relative movement of the surrounding objects, far and near objects will have a difference of velocity and direction. The mainly character is motion parallax.

Motion parallax is caused by the relative movement between the viewer and object. Such movement changes the size and location of object show on the retina, to bring a sense of depth. When the objects with different distance have different motion range on the retina at the same time, motion parallax is engendered. Once rotating head slightly, the relationship between vision and objects has changed the activities of head and body caused the changes. When we watched the scene through window on a move forward train, the poles nearby go backward rapidly, some of the remote fields, buildings moved backward more slowly. The difference of velocity among the objects in view, is an important indicator to estimate the relative distance of them.

(2) Binocular Cues

Binocular depth cues are referred to the depth cues provided by binocular vision. Although monocular cues can provide people lots of depth cues, help people to finish the operation tasks with the visual guidance. However, some depth information must be provided by both eyes.

Binocular Parallax

Since the existence of two eye space between (average being 6.5cm), the two eyes look the object from different perspective actually, the line of sight has a bit different. So for the same object, the relative position of eyes is different, which caused the binocular parallax, that is, the image in each eye is different. The binocular depth cues is changing with the distance increasing, when the distance over 1,300 m, as visual axis parallel, binocular parallax become zero, so it will not work to the distance judgement.

Oculomotor Cues

Accommodation is the eye initiative focusing action. The focus can be accurate adjustive by the crystal body. The adjustment of crystal body is realized by the muscle working, so the feedback of muscle move information helped the three-dimensional sense establishment.

Convergence is that the visual axis gathered to the regardanted object with the distance changing. Convergence is a binocular function, to get a clear video.

2.1.2 Vision and Reaction Time

(1) Vision Feature

Human beings obtained at least 80 percent of the important information of outside world by vision, such as size, brightness, color, movement, which is the most important feeling. After years of experiments, we know that the process of human visual perception has the following feature:

When we observe objects, the visual line are conditioned to the path from left to right, top to bottom and clockwise movement; eye movement in the horizontal direction priority in vertical direction, the estimated of horizontal direction size and proportion is accurate and rapid than the vertical direction.

When the observation of objects deviation from centre in the same conditions, the sequence of observation is: the left upper quadrant is optimal, and then are the right upper quadrant, the left lower quadrant, and the worst is the right lower quadrant.

There is a relationship between color contrast and the human eye capacity for differentiating colors. When people distinguish a variety of different colors from afar, the extent of how easily identifying is followed by red, green, yellow and white. The two-color match case is, black on the yellow background, white on the black, white on the blue, black on the white, and so on.

(2) Reaction time

Reaction time is the elapsed time between the presentation of a sensory stimulus and the subsequent behavioral response. First the stimulation act on sensory, aroused the excitation, then the excitation spread to the brain and processed, and next it spread through the channel to the locomotor organ, locomotor bioreactor receive nerve impulses, produce a certain reaction, this process can be measured with time that is the reaction time.

F.C.Donders had divided the reaction time into three categories, simple reaction time, choice reaction time and discriminative reaction time. Simple reaction time is usually defined as the time required for an observer to detect the presence of a stimulus. Choice reaction time tasks require distinct responses for each possible class of stimulus. Discriminative reaction time is usually stimulate more than one, but only asked for one stimulus to act a fixed response, and others didn’t reaction. The factor impact on the reaction time is in four areas, respectively: stimulated sensory organ, the intensity of stimulation, the time and space characteristic of stimulation, last one is the adaptation state of organ.

2.1.3 Motion Vision

The photoreceptor cell of human eye need a course of time, to identify the signal showed on the retina since imaging. When the view point moving, the objects image show on the retina would also move with a certain angular velocity. When the objects move slowly, it can be accurately identified, but if the speed to a certain extent, people would not accurately distinguish the objects.

The visual feature have a lot of difference between the observation of moving objects and static objects, the mainly aspects is the following areas: visual acuity, visual field, space identify range. And the visual acuity is acuteness or clearness of vision, especially form vision, which is dependent on the sharpness of the retinal focus within the eye and the sensitivity of the interpretative of the interpretative faculty of the brain. The visual field is the space or range within which objects are visible to the immobile eyes at a given time. The space identify range is the ability of identification, such as the size of object, the motion state and the spatial distance. For the moving object, the shorter distance it off observer, the bigger angular velocity it got, the more difficult to distinguish it clearly. And the impact factor of motion vision concluding the relative velocity, age, the color and intensity of the target, and so on.

2.2 3D UI Interactive Principles

2.2.1 Hierarchical Semantic model of "UE"

User experience is widely affecting all aspects of the user's experience when they using a product (or a service). It refers to users' pure subjective psychological experiences. UE in 3D UI is more important than in 2D UI. The designer should meet the users' spirit needs after the psychological needs by effective design strategy. UE mainly come from the interactive process of 3D UI. The purposes of visual design about the 3D UI is to convey some information to attract users. Visual means can improve the quality of experiments. Shneiderman and Nielson, two research pioneers of HCI domain, respectively conclude design goals of interactive systems from the consideration of user interface design and usability engineering (e.g., see Table 1).

No.	Ben Shneiderman	Jakob Nielson
①	Learning Time	Learn ability
②	Executing Time	Efficiency
③	User Retention	Memo ability
④	Error Rate	Errors
⑤	Subjective Satisfaction	Satisfaction

Table 1. Interactive System Design Goal

Actually, user experience may be influenced by all these factors above. Experience is the result of interaction between human and artifact (or other creature) in specific context and accommodated by intrinsic、 psychological and individual surroundings which is composed of motivation、experience、habitude and a variety of cognitive factor. In order to measure user experience's level and compare it with different kinds of interactive system, a new concept----EQ (Enjoyment Quality) is introduced and a hierarchical semantic differential model based on EQ is established (e.g., see Fig. 9).

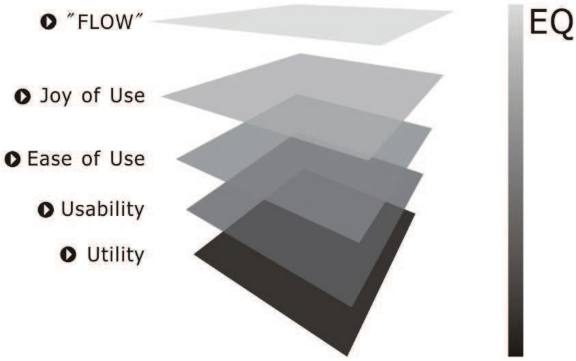


Figure 9. Semantic Differential Model for Measuring "User Experience"

In this model, we utilize five HCI glossaries "Utility", "Usability", "Ease of Use", "Joy of Use" and "the Phenomena of FLOW" to describe user experience, in which the semantic differential is able to represent different level of EQ. Although its scientificalness is yet being further proved, the model is able to indicate orientation of user experience in different systems.

With regard to "different systems", we further divide interactive systems into three groups by referring to Shneiderman's theory: key system, everyday application, and computer games .Obviously, computer games are the most representative one.

- Key system

The application of key system includes transportation control, nuclear reactor system, and military operation and so on. Their chief design goal is "Utility". In order to ensure that operators under high pressure manage to operate quickly with no errors, long time training is always necessary. In fact, adding some hedonic factors to these systems may seriously affects the system performance on its reliability and stability, so such issues are supposed to be taken into prudent consideration

- Everyday application

Everyday application includes industrial and commercial application, office application, and home application. Disordered display, complicated and stuffy operation process, incomplete function, inconsistent task sequence, and inadequate feedback information can be seen here and there [3], so "Usability" and "Ease of Use" are emphasized repeatedly.

Benefiting from the twenty years' development with usability engineering, such problems are being paid attention to and being gradually solved efficiently. The design goal of this group is moving: Usability has become an acknowledged quality aspect of a wide variety of technical products, ranging from software to washing machines. However it recently acquired a new associate, the so-called "Joy of Use". Enhances the non-entertainment system the user experience already is the information system design important idea.

2.2.2 Cognitive Scenario-based GSOMS interactional model

A group of influential theorists at Carnegie Mellon University take the views that decompose the user behavior into small acts of measurable steps to analyze layer by layer. They propose an important model: the goals, operators, methods and selection rules. The GOMS model assumes that users begin with forming the goal (edit documents) and the sub target, and then achieve each goal through methods and process (for example move the cursor to destination through a combination of the cursor key). The change of the user's mental state or the task environment should executive the operator, which includes basic sense, movement and cognition action. Selection rules select one control structure from several optional methods to achieve a goal (for example deletes repeat by the backspace key or deletes the select region by delete button).

Figure 10. Cognitive-Based Interaction Model

3D UI adopt mission analysis to describe users' behavior of each step, including identifying task, cognizing scenario, executing action, perceiving feedback, evaluating result. User's cognitive scenario decides the users' behavior. Obviously, this is where the GSOMS come out, although the original GOMS brought up by Card was once considered as the most successful user behavior model. However, if this model is applied in a tri-dimensional environment, for example, because one feature of tri-dimensional environment is "Scenario", some demerits will appear in the 3D computer games. According to Norman, "The basic challenge which people in different areas faced is the output of knowledge, rather than reproduction (copy) knowledge."Scenario is the extremely effective channel for user to form comprehensive cognition of environment, so scenario-based user interface could help user perform exact, reasonable, habitual operation. And the non-entertainment system is out of scenario and convey with symbols. It values the knowledge that is far away from the real situation, which brings difficulties to cognitive. Recently the cognitive scenario has become a theory based on study, which provide meaningful study and promote the knowledge transform to real life. Therefore, it is very necessary to extend the GOMS model into GSOMS (the Goal, Scenarios, Operators, Methods and Selection rules) model. The interactive model of tri-dimensional information system is based on the users' scenario behavior process (e.g., see Fig. 10).

2.2.3 Screen Layout for Information Minimization

Designer should focus on the layout of the interface to consider the arrangements in the 3D UI, in order to achieve information minimization. We will analyze it from psychology, interactive design, information display and other aspects. In the tri-dimensional environment, users' task is very complicate, from objects accurate movement to the overall situation control. The system offers highly effective resolution, including user behavior process, the design metaphors of the task, information minimization and immediate feedback effect.

3D UI, as a complex system, consists of numerous elements. And more and more information and data user needed to be dealt with appears. Therefore, interactive design should adopt a screen layout with compact and distinct information classification (e.g., see Fig. 11).

Figure 11. Screen Layout

The screen consists of three parts that are always visible: "Top", "Main Window", and "Bottom".

- Top

The top tool bar includes the scene property of the users, time icon, and so on. Here to provide users for the state and the information directly, so that users can gain the information in need during the shortest time.

- Main Window

The main window shows the detail information with maximum screen. It always shows as god view, and the objects show as rich-information (form, size, shadow, texture, lights and so on).It is called Isometric Projection.

- Bottom

The bottom is the navigation area, including the map navigation, the movement navigation and so on. The narrow sense navigation information was refers to the geography object the positional information, the generalized navigation also should include other function readout which the system provided. In the large-scale 3D scene, Navigation is very significant, by which users know their location and the way to arrive the target area. There is a navigation map of a 3D game, as shown in Fig. 12. On the one hand it distinguish different camps and terrain information through different colors, on the other hand, it reflect the important events through graphical animation. These embody the landmark knowledge, road knowledge and overall knowledge, and the combination of overall navigation and process navigation is another strategy of human-computer interaction.

Figure 12. Navigation Map

Different is in the 3D contact surface needs to unify the concrete mission requirement with the traditional 2D contact surface to carry on the dynamic operation, and to pays the territory the attention to be extremely intense. When basis operation the field of vision region gaze spatial frequency distribution, the gaze the duration, the gaze assigns target and so on sequence, level and vertical glance path scope and number of times examines the appraisal, this kind of three surface layout reasonable has manifested the dynamic sight/attention territory assignment, and is advantageous for the operation.

3. 3D UI interactive technical analysis

This part discussed the interactive technology which is used in most common 3D interactive task. It clearly expounded the basic elements of 3D UI: Manipulation, Navigation and System Control, and the following is arranged in accordance with the user's interactive mission analysis.

3.1 Summarization of 3D UI Interactive Technology

Interactive technology is the manner that performs a specific interactive task by using interactive devices. Users can use the same type of interactive devices, and use different interactive techniques to perform an interactive task. The change of interactive devices, implement methods and algorithms produced a wide range of interactive technology which served interactive services ultimately. Bowman first sorted the existing interactive technology from the three levels which are task, sub-task, and implement technology and proposed this design method based on this classification. As shown in Fig. 13.

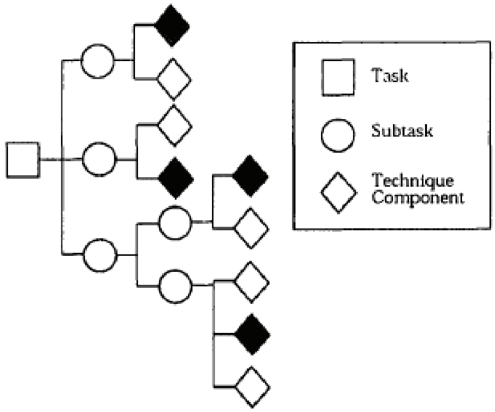


Figure 13. Classification of Bowman

Based on this classification, an interactive task is firstly divided into several sub-tasks, and each sub-task continues to be divided into smaller sub-tasks until there is an interactive technology that can complete this sub-task. These classifications mean can not only discover the affecting variables of interactive technology, but also can guide to design interactive technology. Through the combination the realization technology of different tasks we can easily find new interactive technology. Although it can not guarantee that each combination can get satisfied users' performance, it provides designers a more comprehensive design space. This method is particularly effective when interactive technology options of each sub-task are limited.

3.2 Manipulation

Choice and manipulation are one of the most fundamental tasks not only in the physical environment but also the virtual. If a user can not manipulate and choose the virtual objects effectively, many of the specific application tasks can not be implemented. People's hand is a remarkable device. It allows us to spend less intuitive sense to operate physical objects fast and accurately. The goal of studying manipulation Interface is to enhance the users' capability and comfort, and gradually narrow the impact caused by human inherent habits and hardware restrictions.

3.2.1 Introduction of the concept

Manipulation in reality usually refers to the action that people bring to the objects. In the 3D UI we restricted this action to the rigid objects, that is, the shape of the object does not