UNIT V APPLICATION OF VR IN DIGITAL ENTERTAINMENT

VR Technology in Film & TV Production.VR Technology in Physical Exercises and Games. Demonstration of Digital Entertainment by VR.3D user interfaces - Why 3D user interfaces. Major user tasks in VE. Interaction techniques for selection, manipulation and navigation.3DUI evaluation.

Applications of Virtual Reality in Entertainment include -

- Video games
- Virtual Museums
- Galleries
- Theatre
- Virtual theme parks
- Music VR experience

VR and the Entertainment Industry

One main industry benefiting from the virtual reality is the entertainment business. The human need to continually seek new and innovative ways to relax and energise leads many to the theatre or concert hall. The music industry uses VR to allow those in rural areas far from concert venues or those with certain diseases rendering exposure to crowds and loud noise painful to enjoy their favourite artists even when they cannot attend live. VR concerts give fans around the world a front row seat to some of the hottest bands for a fraction of the price of VIP admission. Virtual reality technology possesses the ability to bring dead artists back to life, at least in fans' earbuds or on a screen.

The Future of VR and the Entertainment World

As technology advances, the entertainment world will inevitably change with it. Instead of wearing funky cardboard red-and-green glasses to watch a 3D movie, theatre-goers will don VR headsets and truly immerse themselves in the action from scene one to the closing credits. The movement to bigger, better, more realistic action in movie and video game markets opens a world of opportunity for investors to collaborate on luxurious new entertainment venues. Many theatres have already added amenities such as luxurious-comfortable seating, improved snack selections and even table-side meal service. Introducing a VR component by adding viewing rooms replete with headsets or even movie seats that rock and slide along with the on-screen action will delight audiences. Staffed VR arcade rooms can give busy parents a break so they can catch a flick while their children play. If used correctly, VR technology holds the power to transform the entertainment world.

I. VR Technology in Film & TV Production

In recent years, VR virtual reality has gradually become a hot topic in society. As a medium integrating computer technology, imaging technology and human-computer interaction technology, VR brings both a new interactive narrative method in the evolution of media and new means of communication in the era of text change. The application of VR technology in the late stage of film and television has promoted the development of diversified creation and the development of film and television post production. At the same time, the application of VR technology has improved the efficiency of film and television production, reduced the cost of physical setting, and saved resources.

With the good word-of-mouth and display effects achieved by the broadcast of some science fiction movies around the world, people have begun to apply modern technologies such as IMAX and 4K to the production of film and television. Among them, the emergence of VR virtual technology has also officially become a new entry point for film and television art application technology after 3D technology. Many well-known film and television companies apply VR virtual technology in film and television production, which fully reflects the development prospects of VR virtual technology. In the exploration of VR image production and the corresponding industry talents, some domestic and foreign companies and universities have taken the lead in the industry. Although many Chinese film and television production companies use VR virtual technology, the application of VR in film is still in the state of exploration and development. Throughout the history of film development, film art and technology are closely linked. The development of virtual reality in the film field has created the glory of contemporary film. The combination of virtual reality technology and film art has changed the form and nature of film images, thereby affecting the artistic effect of films.

With the advent of the digital age, more and more films are using VR in the production process of movies, especially in surreal movies such as science fiction and magic. Virtual reality technology has made movies have an unprecedented shocking effect on the audience in terms of audiovisual experience, and even to a certain extent is more imaginative and artistically appealing than traditional movies. However, compared with Hollywood in the United States, the level of industrialization of domestic films is relatively backward, and the technological innovation and application capabilities are obviously insufficient. The full advantages of virtual reality technology have not been fully utilized.

The application of VR virtual reality in film and television post-production has made the film and television industry to diversify the creation of works, further promote the development of film and television post-production, and improve the overall level of post-production. At the same time, the application of VR technology improves the efficiency of film, reduces the cost of real scene setting, and saves resources.

VR technology is a three-dimensional virtual environment built using computer technology. This technology can make movies, animations and games into three-dimensional, so that the user experience will be improved. Users can have an immersive feel to movies and games. Under the technology that realizes visual 3D, the sound also achieves 3D effects. The surrounding sound also has a 3D feel. With the support of such technology, users are very fond of film and television works processed by VR technology, which also indirectly makes animation and digital imaging in colleges and universities. The synthesis profession has paid more and more attention to VR technology in the post-production of film and television. In fact, VR technology actually increases the human-computer interaction experience, making users more and more realistic about using machines, watching movies and playing games with an immersive feeling, such technology not only aroused People's interest in movie games and other activities can also make movie special effects and game feel more cool. All in all, the emergence of VR technology has directly subverted people's views on a series of activities such as watching movies and playing games. The previous activities were just the users watching, but the current activities are the users' feelings. Such an experience is deeply loved by people. The application of VR technology is very extensive. In addition to film post-production and 3D effects of games in the film and television industry, there are also some commonly used applications, such as virtual test makeup and dress-up applications on some shopping apps.

Film and Television Post Production

The post-production work of film is mainly to process the various materials that have been shot using unique technology, and cut multiple shots together into a complete film. In the production of film, post-production plays a vital role. It integrates the pre-production and improves the work efficiency to ensure the quality of film and television works. The post-production of film and television needs to wait for the completion of film and television production, and then use the computer production software to complete the editing and processing of the film. Film and television post-production is a relatively complicated link, which involves a lot of production processes. Use film and television post-production to add a few special effects, and edit and piece together the previously filmed video clips to finally present a complete film and television work.

The main steps of film and television post-production can be divided into the following three points:

(1) Editing of the lens

In the post-production of film and television works, the editing of the lens is the most basic. This part of the work is to get the various shots in the film and television works to be clipped and then pieced together, so that the lenses in the film and television works have a rough arrangement. Drawing on the guidance of film producers, getting regular cuts of film and television productions, and then reorganizing them, arranging the shots with no central idea or order at first into a logical, orderly and organized Storytelling footage are the parts of post- production of film. The director's ideas have a direct bearing on the pros and cons of a film and television work, and of course the editor's skills are also very important.

(2) Sound editing

An important component of film and television works is sound. In the post-production process, the sound should be processed while editing the lens, such as soundtrack and dubbing. At present, there are two kinds of dubbing methods. First, simultaneous recording, and when editing the sound later, the edited sound should match the edited picture, so that the dubbing can be complete and synchronized with the story picture and development in the work; Second, post-dubbing. This kind of dubbing does not require too much technical content. Usually, the lens is cut first and then dubbed by the dubbing staff. In the later stage, only the volume needs to be simply adjusted. The soundtrack of an excellent film and television work is often more attractive. It needs to be combined with the theme of the story to render the atmosphere of the entire play, and it will help to create a situation.

(3) Synthesis of special effects

In the post-production of film, a very important environment is the production of special effects. The development of special effects has a long history. Currently widely used is a film and television production technology that is gradually moving towards high-end. In the production process, in order to achieve the ideal artistic effect, some advanced special effects technology must be used, so 3D technology appears more and more frequently. At present, 3D technology is widely used in various film and television works. VR virtual reality technology is a three-dimensional virtual environment built using computer technology. This technology can make movies and animations into three-dimensional, give users a immersive feeling, and let the audience have a better viewing experience.

(1) VR virtual reality improves film efficiency

The design of VR virtual scene and the application of virtual shooting system have greatly improved the shooting efficiency, saved the crew transition time, and the shooting is not affected by weather and light, which shortens the shooting cycle. In addition, the creative space for post-production has been increased. The virtual scene can be adjusted later, which changes the traditional “shoot-and-make” mode. Although the post-production workload has increased relatively, using “post-front” can also compress. The post-production process can save the time of the virtual camera tracking and matching. At the same time, the on-site shooting departments can monitor the pre-compositing screen in real time to avoid scheduling confusion.

(2) VR virtual reality technology reduces movie production costs

The use of VR virtual reality technology to design virtual movie scenes can greatly save the material costs and labor costs of real scene scenes, and save resources. Because the physical setting is generally not recyclable, it is often demolished after shooting, which wastes resources and is not conducive to environmental protection. The virtual movie scene saves the achievement of physical setting.

(3) Problems in VR post-production in film and television

The design of VR virtual scenes and the application of the virtual preview shooting system have increased the technical staff of on-site shooting to a certain extent, which is relatively more complicated and demanding than the traditional shooting process, and the cost of post-production will also increase. However, as a whole, the production cost is reduced, but it is not suitable for all types of film and television production. VR virtual reality technology should be combined with the needs of the film itself, do not use VR technology as a gimmick for film and television. Only with a reasonable fusion of art and technology can VR virtual reality technology develop and progress in the film and television industry.

The main purpose of the production of film is to present an exquisite film and television work to the audience, so that the audience's demand for film and television work is fully satisfied. The application of VR virtual reality in film and television post-production has made the film and television industry to diversify the creation of works, further promote the development of film and television post production, and improve the overall level of post-production. Although the bottleneck of VR virtual reality in film and television post-production still exists, its advantages are also quite obvious. It improves the efficiency of film and television production, saves the setting cost, and avoids waste of resources. As long as the reasonable integration of art and technology, and according to the needs of the film itself, VR virtual reality technology can get better development and progress in the film and television industry.

II. VR Technology in Physical Exercises and Games

Video Games as Physical Education

Virtual reality technology, which turns users into active participants, is dramatically changing the way kids play video games. In a VR game, a user can play a sport or dance as part of the game — which means they actually move their body, not just their pupils and thumbs. The Valley Day School in Morrisville, became the first in the country to install a high-tech, state-of-the-art virtual gym, complete with camera sensors and stereo sound, 3D projectors and other gaming accessories.

The immersive VR setup transforms PE class into a “life-size video game” for the students. Improving the level of physical activity in children through VR-based games is welcome news for parents and educators because video games have been singled out as a main culprit responsible for the plummeting levels of physical activity among children. The Centers for Disease Control and Prevention noteg that 1 out of 6 children and teenagers in the country are obese. “In 2014, the CDC identified hours playing video games as one of the risk factors for low physical activity in the United States”. But adding VR to the PE mix flips this scenario on its head. It is been stated that, “the inherent movement in virtual reality and augmented exercise make it possible that video games may soon be a positive contributor to physical fitness. And the popularity of video games as one of the world’s most sustained and growing pastimes may make it a great ally for those that traditionally struggle with staying fit”.

VR Exercise Games Tackle Obesity and Aid the Disabled

The general public is also looking more at using VR games to boost exercise, according to The New York Times. Some people have injuries or disabilities that prevent them from traditional forms of exercise, and anecdotal evidence suggests that VR video games with an exercise component can help them maintain their fitness levels. A 2019 study by the Journal of Special Education Technology called such games “a promising tool” to help kids achieve the recommended minimum daily amount of 30 minutes of moderate physical activity. Among the more popular games are Oculus Quest’s Beat Sabre, Box VR, The Thrill of the Fight, SoundBoxing and Holopoint, to name a few. Another study cited in the journal’s study noted that “physical activity is a key factor in preventing health problems that result from leading a sedentary lifestyle and can positively impact the health, fitness, and behavior of adults and youth.”

The Virtual Reality Institute of Health and Exercise and the Kinesiology department at San Francisco State University have teamed up to develop the VR Health Exercise Tracker “built on hundreds of hours of VR-specific metabolic testing using research-grade equipment.” The tracker collects metabolic data, including number of calories burned.

A good personal computer, VR headset (ranging in price from $350 to $800) and 6 square feet in which to move around are all a user needs to play these video fitness games, reported CNN. That means many institutions can easily make space for gamers and spur students to get off their mobile phones and tablets — and students won’t even realize they are exercising.

Is Virtual Reality the Future of Exercise?

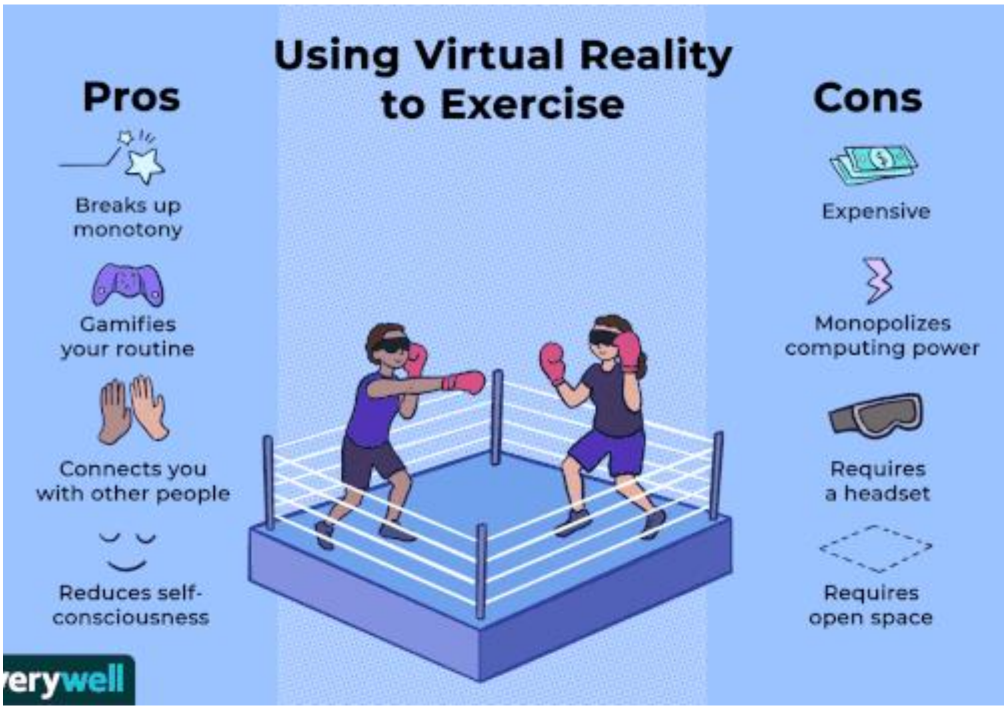

Fig. 5.1 Pros and Cons of using VR to Exercise

There's probably not a person on this planet who hasn't wanted to escape their reality in the middle of a tough workout. Huffing and puffing on a stationary bike (or some other piece of equipment) surrounded by hordes of other sweaty people counting down the minutes until they've met their goals, is rarely an exciting experience.

And while true virtual reality platforms—where a person's environment is completely replaced by a digital one—are still barely scratching the surface of the fitness world as of 2019, the industry is growing, and for good reason. "In 2018 VR is estimated to have grown 30%, largely due to the popularity of the PlayStation VR. The launch of (Facebook's) Oculus Quest (in 2019) is expected to be another huge leap forward," says Jordan Higgins, Head of Immersive Experience at U.Group, where its emerging tech incubator, ByteCubed Labs owns PRE-GAME PREP, a holographic football training system.

"Fitness applications are more supplemental than they are a primary form of exercise, but the novelty can do a lot to break up a monotonous workout routine." The idea being that you can be transported to a beautiful location like the Swiss Alps for your next stationary bike ride, rather than having to stare at the sweaty back of a fellow gym-goer. But it's not just the ability to "escape" the real world that makes virtual reality platforms an exciting new world for exercise. Due to the internet-connected nature of VR headsets and other devices, tracking and monitoring key health metrics also becomes more accessible for users. "New data points can be tracked for better insight into performance". "And combining immersive VR with other wearable sensors like the Apple Watch, you can really start to see a connected ecosystem that will drive the next generation of immersive fitness."

Pros of Using Virtual Reality for Fitness

As with any exercise trend, there are always benefits and drawbacks to jumping on the bandwagon. Given that virtual reality is more of a platform for different types of exercise than a form of exercise in-and-of-itself, it should be considered a generally safe and reasonable option for those who want to try it out. It should come as no surprise that it's going to be more appealing to those who are interested in gaming, technology, and tracking performance metrics than those who try to live their lives in a more disconnected, "off-grid" fashion. That said, everyone should consider the pros and cons before diving in headfirst.

Breaking Up Monotony

The most dedicated exercisers seem to have no problem hitting the gym every day, doing more-or-less the same workout, and continuing the trend ad nauseam. Trainers like to tout the importance of creating a habit, developing internal motivation, and looking for intrinsic rewards to help you continue to exercise. The reality is, though, that most people struggle with this no-nonsense approach. Doing the same workout day-in and day-out can lead to boredom and disenchantment with exercise. Due to the internet-connected nature of VR headsets and other devices, tracking and monitoring key health metrics also becomes more accessible for users.

"Gone is the drudgery of doing the same old workout routine in a crowded and stinky gym," says Mat Chacon, the CEO of VR company Doghead Simulations, and a VR-exercise advocate who went from fat-to-fit by working out in VR. "People can use VR to transport to any environment they desire—the moon, the beach, under the ocean, or wherever they want. Using VR, people can even load a 3D model of a boxing ring and practice ducks and slips and then do yoga in a Japanese zen garden without ever leaving their home." The endless opportunities for novelty in workouts, environment, and even the people you choose to interact within a connected, online world is one of the greatest benefits for those who often grow bored with the same old routine.

Gamification

The beauty of exercising in a 3D virtual environment is that you can move and interact within games themselves. These technologies, which essentially turn the workout experience into a virtual competition—with yourself or with others—can keep exercise fun while helping to distract you from the work you're actually doing. As of 2019, the number of full-fledged VR games designed specifically for exercise is relatively low, but there are games that, by their very nature, require full-body movement within the virtual environment, turning them into a workout. "I would argue the best, and most viral form of exercise mixed into gaming would be from the game Beat Saber," says Steve Kamb, the founder of NerdFitness, a website dedicated to helping nerds and gamers get fit. "Think of it like Guitar Hero, except it's immersive, and you're playing drums and dodging blocks, and getting a really solid cardiovascular experience." But Beat Saber isn't the only option—Kamb mentions Creed: Rise to Glory and First Person Tennis as other popular options—and as the interest in VR for exercise grows, developers will continue bringing more new games to the market.

"Gymtimidation" is a very real experience for people new to exercise or those who are trying a workout for the first time. For any number of reasons, you may feel self-conscious or out-of-place, whether it's because you're thinking about your body or fitness level, you don't know how to use the equipment or do the exercises, or you just don't know anyone at the gym. VR pretty much wipes out all those concerns. VR provides a support network and avatars actually give people a 'mask' to hide any insecurities and fears that might be preventing them from going to a more traditional gym or fitness class. People may also open up more than they might in a face-to-face setting or within a video chat.

Connection with Others

Given that virtual reality platforms and games are connected to the Internet, you can quite literally connect with other users all over the world. And not just other gamers. "You can interact with coaches in Brazil, meal planners in New York, or yoga instructors in Mumbai," Chacon says. "You can see each other and interact as though you're all in the same place at the same time. It's nice to high-five fellow VR workout participants and encourage each other to keep going."

No Waiting for Equipment

Most people use VR systems within the comfort of their own homes, which means they can simply log in and start exercising whenever they have time. This beats having to sign up early for a popular class or waiting in line for a treadmill or bench press during peak hours at the gym.

Cons of Virtual Reality and Exercise

Cost of VR Systems

The earliest iterations of VR devices, like most new technologies, were incredibly expensive, making purchase by the general public largely infeasible. But as technology has improved and more companies have entered the market, the cost of tethered and untethered systems continues to drop.

As of 2020, the Oculus Quest ranges from $399 to $499, the pared-down Oculus Go ranges from $199 to $249, PlayStation VR bundles start at $299, and HTC Vive prices start at more than $600. Of course, these are consumer-friendly headset systems that don't offer some of the features that more extensive VR systems include (some use full bodysuits and specialized treadmills), but they still aren't a price everyone can afford.

Certainly, you wouldn't want to throw down several hundred dollars for a VR system if you weren't completely confident you'd enjoy your exercise experience.

Computing Power

If you're electing to use computer-based VR systems, you need to make sure your computer's specs measure up, and if you're running VR through your home internet connection, you need to make sure you have enough bandwidth to load the graphics and keep the system running seamlessly. "You should make sure you have enough horsepower to run the VR software you like," says Jeanette DePatie, a certified fitness trainer who has spoken at tradeshows like CES about virtual reality and other technologies. "VR requires massive amounts of computing power, so you probably won't be able to run current or future games on your computer unless it's souped-up with the latest processors and graphics chips." - Jeanette DePatie

Wearing a Headset While Exercising

To replace your real-world environment with a virtual 3D environment, you have to wear a headset. Some of these headsets are tethered to an external system, which means you have to work around a physical tether, while other headsets are stand-alone. These stand-alone headsets are either connected wirelessly to an external system or are stand-alone units that enable you to interact in a virtual environment without having to stay within range of connected sensors.

Regardless, the headset is a requirement of virtual reality exercise, and it's not something that will appeal to everyone. Wearing a VR headset isn't necessarily that different from wearing a heavier pair of snowboard goggles, but the headset will naturally restrict your view of your real-world environment, and to stay secure, you'll need to secure them snugly to your head. If either of these requirements sounds uncomfortable, you may not want to test the waters of VR exercise.

All the Sweat

Even if you're comfortable with the idea of wearing a headset while exercising, you need to remember that you'll be wearing a headset while sweating. "I can't stress this enough—invest in cleaning wipes and a headset cover," says Higgins. The wipes keep your headset clean and hygienic for each successive workout, and the headset cover makes it easier to clean and more comfortable to wear.

Space Requirements

Wearing a headset while exercising can be a difficult while doing workout. If the view of your living room is blocked out and replaced with an empty boxing ring, you may inadvertently run into your coffee table or trip over your dog. Whenever possible, set up your VR system in a wide-open environment that's unlikely to be interrupted by other people or animals during your workouts.

Virtual Reality Gyms

If you're not ready to buy your own VR system, but you'd like to see what it's like to work out in a virtual environment, keep an eye on the gyms opening up in your area. The first-ever full-fledged VR gym, Black Box, opened in San Francisco in 2019, and entrepreneurs in other large cities are likely to follow suit, proving that VR really might be the future of exercise.

Running virtual:

The effect of virtual reality on exercise Research has shown that exercise among college aged persons has dropped over recent years. Many factors could be contributing to this reduction in exercise including: large workloads, the need to work during school, or perhaps technology use. A number of recent studies are showing the benefits of using virtual reality systems in exercise and are demonstrating that the use of such technology can lead to an increase in the number of young adults engaging in exercise. This study focuses on the effects that virtual reality has on heart rate and other bodily sensations during a typical work out. This study also analyses the participants' ability to pay less attention to their bodily sensations during exercise when using a virtual reality system. During this experiment, participants were exposed to two different conditions. Condition one being a traditional work out, riding an exercise bike at a middle tension level. Condition two was the same but the participant was wearing a virtual reality headset. The data collected led to the conclusion that working out while wearing a virtual reality headset will lead to a higher heart rate, and in turn can lead to burning more calories during a workout. The study also found participants who wore the virtual reality headset were able to remove themselves from their bodily sensations allowing them to workout longer. Virtual reality fitness can be a great way to build fitness confidence. (And having great workouts available from home is even more important now since many gyms still remain closed due to the COVID-19 pandemic.)

Turn Your Workout into a Game: VR and the Future of Fitness

Digital technology has already transformed fitness. Your smartphone counts your daily steps; lightweight, wireless-enabled watches and other "wearables" can monitor your heart rate and vital statistics; and gym equipment with built-in workout tracking and video monitors can take your workout to anyplace on the planet. Before you take a breather from your virtual at-home spin class or let your smart watch sync with your sleep app and hourly analytics, make room for virtual reality (VR). Not only will VR enhance the overall workout experience, but it will also address obstacles to exercise — a lack of motivation and our natural preference to conserve energy and avoid activity. Because VR is emerging as the next big computing and consumer platform (following the emergence of the internet and mobile devices), it should be no surprise to see VR driving innovation across industries and use cases, such as architecture, mental health and education.

The VR Opportunity

Ryan DeLuca and Preston Lewis spent 17 years growing a leading e-commerce site that provided information about sports and fitness and sold nutritional supplements. It became very successful, with more than 30 million fitness enthusiasts visiting it each month. In 2015, the duo decided to start a new venture combining their loves for fitness and technology. After three years, Black Box VR launched, a virtual reality gym. They sign up for the gym in January and stop going in March. They lapse. They stop showing up, even once a week. Even the most advanced scientists and doctors haven't figured out a solution to this problem.
The traditional gym is being changed into a game –
Black Box VR isn't the only one making moves into the VR fitness market.

- WalkOVR has created a system of sensors that attach to the knees, ankles and torso to record lower body movement, making it possible to run in virtual environments while staying put in reality. The product was designed with fitness in mind but is also compatible with games that are not necessarily fitness related.
- BoxVR received VR Fitness Insider's 2017 Best VR Fitness Game of the Year for its at-home VR boxing workout where the user punches to a rhythmic beat. Developed by fitness instructors, it's like a VR Tae-Bo video, minus the three easy payments of $19.99 plus shipping and handling.
- VirZOOM's "VZfit Sensor Kit" attaches to any stationary bike to turn it into a VR cycling experience. In the VR world, the cyclist can bicycle through real destinations or fly Pegasus through a canyon.

Turning workouts into a game is a genius move — capitalizing on our human need for instant rewards and achievements from a game versus waiting days or even weeks to see physical results from a workout.

A key benefit of a VR workout is consistency and tracking. Entire markets are devoted to tracking workouts; you may be wearing one on your wrist right now. Virtual reality hardware is designed to track movements to enable the user to interact with the virtual environment. These sensors and accelerometers can track even the most minute movements, making it a very efficient medium for tracking a workout. The effort that was put into VR workout will have immediate in-game rewards and long-term health benefits. Sure, it may feel like as if the users are playing a game and having fun.

III. Demonstration of Digital Entertainment by VR

People spend a lot of time and money on video games, social networks, cinema, amusement parks, music concerts, and sports games. Most likely, virtual reality will not replace these entertainments, but it can make them more inclusive and immersive. In the last few years, using virtual reality for entertainment has been mainly experimental. Now the VR entertainment market is entering the commercial stage and boasting some profitable projects. Various virtual reality entertainment options are discussed that will even make proper investment decisions.

The Venture Reality Fund states that the total investment in the VR industry reached $2.3 billion in 2017. Almost half of all investments in virtual reality fall on the entertainment sphere. According to Kaleidoscope’s research, in 2017, more than $1 billion was invested in VR entertainment. The Kaleidoscope’s experts forecast that in the coming years, investors will have a significant choice of virtual reality projects that can bring income. An increase in the creation of more lifelike VR entertainment experiences will engage more consumers and boost the commercial success of the virtual entertainment industries.

The VR gaming market generates the highest income compared to other virtual reality entertainments. In 2017, the virtual reality gaming industry made $2.2 billion. At the same time, more than 35 games have earned over $1 million, which is an indicator of healthy competition and the potential of the VR gaming market. PlayStation, Nintendo Wii, and Xbox virtual reality games bring the highest revenue. The consoles attract hardcore players, who are willing to pay for expensive lifelike VR games. Not all players can afford to buy a high-end virtual reality headset and VR controller. However, budget virtual reality glasses, such as Google Cardboard Glasses, allow them to try VR apps with minimal costs. Also, arcades – location-based VR entertainment centers, help promote virtual reality games. In the VR arcade, a user can enjoy immersive experiences for a reasonable fee.

Virtual reality has an extensive application. With its help, traditional types of entertainment can take a new dimension.

Virtual reality is often blamed for leading people to isolation. On the other hand, it can also unite people in virtual worlds. VR worlds are online virtual reality social platforms where people can interact with each other. Communication in the virtual spaces is much like communication in the real world, but it provides almost unlimited possibilities in the choice of settings and ways of spending time. Neurons Inc conducted a survey of USA residents who have never used virtual reality and describe themselves as the late adopters. This study of social interaction revealed that 59% of the respondents consider virtual reality as the desired way of communicating with friends and family who are far away. Interest in VR worlds is fueled by the IT market giants, planning to build a strong VR community. For example, Facebook is now actively promoting its social media VR app Facebook Space. Microsoft also believes in the great future of virtual networks. That's why Microsoft acquired a popular social VR platform AltspaceVR. At the moment the prospective areas for the development of virtual reality worlds are more photorealistic three-dimensional avatars and the creation of exciting and detailed locations.

Theatre

The incredible success of the New York show Sleep No More prompted tremendous interest in the immersive theatre. An immersive or interactive theatre is a dramatic performance, where there is no traditional stage, and the audience is involved in the action. Now the producers of the interactive theatre shows are looking for ways to further immerse the audience into action. One such method is virtual reality. Technical capabilities of VR can accurately convey the main features of the immersive theatre, such as narrative, immersion, and interactivity.

Greenlight Insights research reveals that consumers are most interested in the VR theatre among all virtual reality entertainment. The survey covered more than 2,000 United States residents of different gender, age, and social standing. 66% of respondents were willing to visit the VR theatres. The combination of theatre and virtual reality can create a successful business model. The theatrical VR content supposes clear ways of monetization and can bring stable income for several years, unlike the VR movies, which become irrelevant very quickly due to the low involvement of viewers to the action.

Cinema

The location-based virtual reality entertainment industry is about to grow up to $825 million by 2021 according to Greenlight Insights' forecasts. Cinema can become a leader in this emerging market. Currently, the most successful adept of VR cinema is IMAX. Let's look at how IMAX runs VR movie theatres to reveal the significant factors for their success. It is crucial to choose proper hardware. For example, IMAX applies, among others, the StarVR headsets, which are not available for home use. Thus, it helps to attract VR-enthusiasts who want to try cutting-edge technology. Unique content can also be a prominent competitive advantage. For instance, Justice League VR – the blockbuster created in the Warner Bros. partnership attracted a mass audience in Imax VR centers. The popularity of multidimensional cinemas proves that viewers want to immerse themselves in the movie. Further development in this direction requires the creation of new forms of movie storytelling, which can involve a VR viewer in the action and make the VR movie experience truly immersive.

Museum

Usually, a museum is considered to be entertainment for academics and does not attract a wide audience. With the virtual reality technology, you can engage a large audience to visit the museum. Museums can use virtual reality apps for the location-based virtual reality entertainment. For example, the British Museum used VR devices to engage adults and children with their Bronze Age collections. Visitors in the virtual reality headset could walk through the ancient landscape and interact with the artifacts using a VR controller. Many museums create their virtual reality applications for desktops and mobile devices. After the launch of such virtual applications, museum representatives note an increase in the museum attendance.

Amusement Park

Amusement parks are designed to give people an unusual experience, entertainment, and exciting sensations. This market has very tough competition, with the increasing difficulty to amaze visitors. The combination of virtual reality and rides creates a unique experience and can highlight your amusement park amidst traditional entertainment. Theme parks are trying to carry visitors to an unusual setting. A virtual reality headset truly immerses a user in another world. Moreover, it is much cheaper than the creation of material objects and visual effects. You can create several temporary versions of virtual applications, for example, for Halloween or Christmas, and provide users with the most relevant experience. Usually, consumers enjoy VR attractions, though advanced users often expect more interaction. Also, do not forget that rides can cause vertigo or sickness. Therefore, it is necessary to take care that virtual reality headsets you use are high-quality and comfortable for visitors.

Gallery

Creating a VR application for a gallery is a long-term investment, which will help you gain customer attention and build your loyal audience. Let’s see how you can use VR in the gallery business. The most apparent use of VR is a virtual tour around the gallery. Such virtual reality tours allow people to enjoy the art without having to stand in lines, pursue masterpieces, and sometimes even interact with them. In addition to this, galleries are experimenting with the development of complex interactive VR applications, for example, where the user can create compositions using some patterns. The Tretyakov Gallery in Moscow created such a VR app to engage their wide audience with art. Wearing virtual reality glasses, app users create their paintings in the manner of famous artists and can share them on social media. Most likely, the VR application itself will not bring profit. Still, it is a powerful marketing tool to increase awareness and attract a large number of visitors to your gallery.

Live Music Concerts

Competition in the music industry forces producers and musicians to endless experiments in search of means to keep up with the trend and be attractive to the audience. Let’s look at how the music industry can make use of virtual reality. Today, major music festivals such as Coachella, Lollapalooza, Tomorrowland, Sziget Festival have their VR applications or 360-degree videos. Virtual reality solutions help to scale the festivals, even more, increase their audience and earn on the sale of VR music content. Top artists, for example, Paul McCartney, U2, Björk, Coldplay, Imagine Dragons present their live performances through VR. With the virtual reality headset, spectators are virtually transported to the best seats to immerse in the concert. The VR viewers pay for watching concerts. It brings income to both the artist and the platform hosting VR concerts. A promising direction of VR music performances is fully simulated virtual reality concert. It means that three-dimensional images of artists and the environment around them are created for the show. Thus, VR viewer can visit, for example, a recording studio of the favourite artist and get an entirely new immersive experience in a musical performance.

Live Sports Games

Sports games are the other live events that are popular in a 360-degree format. A person only needs to wear a virtual reality headset to become a VR viewer. Now, to make a profit from broadcasting VR sports games, it's enough to place advertising and take a fee for the possibility of viewing the game through a VR app. Few companies are already broadcasting virtual reality professional sports games. Facebook, for instance, is now streaming VR baseball and VR football games through the platform Oculus Venues. This virtual reality streaming service promises to bring the stadium experience to everybody's home. Of course, at the moment, the emotions that the VR football viewer feels are different from those that the real viewer experiences on the field. Actions on the sports field occur very quickly, so spherical cameras are not able to capture the image and correctly transmit it to the viewer. Further development of motion capture will significantly increase the realism of VR live sports games.

Hobby Lesson

Virtual reality hobby lesson is a perfect mix of education and entertainment, which is often called edutainment. Usually, virtual reality edutainment is used as a marketing tool to promote products and build brands. VR hobby lesson can be a training video in a 360-degree format. Or it can be an interactive VR application, which is more effective in immersing the user in a virtual environment. To watch a VR video, a user only needs to wear virtual reality glasses. And to interact with the VR app, a VR controller is required as well. Virtual reality hobby lessons are great for all age categories. But so far the market has very few proposals for children. If your business is related to children products, VR app in the form of a virtual reality game for kids can help you stand out against similar companies.

Games

New genres of VR games replicate traditional game genres. Therefore, innovative VR games, in particular using specific properties of virtual reality, such as haptic feedback or recognition of smells and flavors, can make a real breakthrough in the industry. The market of virtual reality games for kids is also poorly developed. For a pleasant game experience, a child needs a special small sized virtual reality headset for kids. The development of virtual reality games for kids is no more difficult than developing games for adults. However, the competition in this market is still low, which gives certain competitive advantages. Job Simulator, developed by the Owlchemy Lab, is the game, which managed to become a hit among children and adults. This game became a bestseller and earned more than $3 million in revenue. Job Simulator encourages players to experiment for completing funny tasks, teaches positive role models and is easy to play regardless of age.

On the whole, the combination of the emotional entertainment industry and virtual reality technologies creates products with extraordinary commercial potential. Entertainment and virtual reality industries stimulate each other's growth, attracting more and more consumers. Therefore, traditional venture capital funds and innovative accelerators invest money in VR entertainment.

IV. 3D user interfaces

On desktop computers, good user interface (UI) design is now almost universally recognized as a crucial part of the software and hardware development process. Almost every computing-related product touts itself as “easy to use,” “intuitive,” or “designed with your needs in mind.” For the most part, however, desktop user interfaces have used the same basic principles and designs for the past decade or more. With the advent of virtual environments (VEs), augmented reality, ubiquitous computing, and other “off-the-desktop” technologies, three-dimensional (3D) UI design is now becoming a critical area for developers, students, and researchers to understand.

Modern computer users have become intimately familiar with a specific set of UI components, including input devices such as the mouse and keyboard, output devices such as the monitor, interaction techniques such as drag-and-drop, interface widgets such as pull-down menus, and interface metaphors such as the desktop metaphor. These interface components, however, are often inappropriate for the non-traditional computing environments and applications under development today. For example, a wearable-computer user may be walking down the street, making the use of a keyboard impractical. A head-mounted display in an augmented reality application may have limited resolution, forcing the redesign of text-intensive interface components such as dialog boxes. A virtual reality application may allow a user to place an object anywhere in 3D space, with any orientation—a task for which a 2D mouse is inadequate. Thus, these non-traditional systems need a new set of interface components: new devices, new techniques, new metaphors. Some of these new components may be simple refinements of existing components; others must be designed from scratch. Most of these non-traditional environments work in real or virtual 3D space, so these new interfaces are termed as 3D user interfaces.

V. Why 3D user interfaces

1. 3D interaction is relevant to real-world tasks:

Interacting in three dimensions makes intuitive sense for a wide range of applications because of the characteristics of the tasks in these domains and their match with the characteristics of 3D environments. For example, VEs can provide users with a sense of presence (the feeling of “being there”—replacing the physical environment with the virtual one), which makes sense for applications such as gaming, training, and simulation. If a user is immersed and can interact using natural skills, then the application can take advantage of the fact that the user already has a great deal of knowledge about the world. Also, 3D UIs may be more direct or immediate; that is, there is a short “cognitive distance” between a user’s action and the system’s feedback that shows the result of that action. This can allow users to build up complex mental models of how a simulation works, for example.

2. The technology behind 3D UIs is becoming mature:

User interfaces for computer applications are becoming more diverse. Mice, keyboards, windows, menus, and icons—the standard parts of traditional WIMP (Windows, Icons, Mouse, and Pointers) interfaces—are still prevalent, but non-traditional devices and interface components are proliferating rapidly. These include spatial input devices such as trackers, 3D pointing devices, and whole-hand devices that allow gesture-based input. Multisensory 3D output technologies, such as stereoscopic projection displays, head-mounted displays (HMDs), spatial audio systems, and haptic devices are also becoming more common.

3. 3D interaction is difficult:

With this new technology, new problems have also been revealed. People often find it inherently difficult to understand 3D spaces and to perform actions in free space. Although we live and act in a 3D world, the physical world contains many more cues for understanding and constraints and affordances for action that cannot currently be represented accurately in a computer simulation. Therefore, great care must go into the design of user interfaces and interaction techniques for 3D applications. It is clear that simply adapting traditional WIMP interaction styles to 3D does not provide a complete solution to this problem. Rather, novel 3D UIs based on real-world interaction or some other metaphor must be developed.

4. Current 3D UIs are either simple or lack usability:

There are already some applications of 3D user interfaces used by real people in the real world (e.g., walkthroughs, psychiatric treatment, entertainment, and training). Most of these applications, however, contain 3D interaction that is not very complex. More complex 3D interfaces (e.g., immersive design, education, complex scientific visualizations) are difficult to design and evaluate, leading to a lack of usability. Better technology is not the only answer—for example, 30 years of VE technology research have not ensured that today's VEs are usable. Thus, a more thorough treatment of this subject is needed.

5. 3D UI design is an area ripe for further work:

Finally, development of 3D user interfaces is one of the most exciting areas of research in human– computer interaction (HCI) today, providing the next frontier of innovation in the field. A wealth of basic and applied research opportunities are available for those with a solid background in 3D interaction. It is crucial, then, for anyone involved in the design, implementation, or evaluation of nontraditional interactive systems to understand the issues

VI. Major user tasks in VE

Interaction techniques for selection, manipulation and navigation

Selection and Manipulation

The quality of the interaction techniques that allow us to manipulate 3D virtual objects has a profound effect on the quality of the entire 3D UI. Indeed, manipulation is one of the most fundamental tasks for both physical and virtual environments: if the user cannot manipulate virtual objects effectively, many application-specific tasks simply cannot be performed. Therefore, 3D interactions with techniques for selecting and manipulating 3D objects is discussed -

The human hand is a remarkable tool; it allows manipulating physical objects quickly and precisely, with little conscious attention. Therefore, it is not surprising that the design and investigation of manipulation interfaces are important directions in 3D UIs. The goal of manipulation interface design is the development of new interaction techniques or the reuse of existing techniques that facilitate high levels of user-manipulation performance and comfort while diminishing the impact from inherited human and hardware limitations.

3D Manipulation

Software components maps user input captured by input devices, such as the trajectory of the user's hand and button presses, into the desired action in the virtual world (such as selection or rotation of a virtual object). There is an astonishing variety of 3D interaction techniques for manipulation—the result of the creativity and insight of many researchers and designers. They provide a rich selection of ready-to-use interface components or design ideas that can inspire developers in implementing their own variations of manipulation interfaces.

3D Manipulation Tasks

The effectiveness of 3D manipulation techniques greatly depends on the manipulation tasks to which they are applied. The same technique could be intuitive and easy to use in some task conditions and utterly inadequate in others. For example, the techniques needed for the rapid arrangement of virtual objects in immersive modeling applications could be very different from the manipulation techniques used to handle surgical instruments in a medical simulator.

In everyday language, manipulation usually refers to any act of handling physical objects with one or two hands. For the practical purpose of designing and evaluating 3D manipulation techniques, we narrow the definition of the manipulation task to spatial rigid object manipulation—that is, manipulations that preserve the shape of objects. This definition is consistent with an earlier definition of the manipulation task in 2D UIs as well as earlier human and motion analysis literature.

However, even within this narrower definition there are still many variations of manipulation tasks characterized by a multitude of variables, such as application goals, object sizes, object shapes, the distance from objects to the user, characteristics of the physical environment, and the physical and psychological states of the user. Designing and evaluating interaction techniques for every conceivable combination of these variables is not feasible; instead, interaction techniques are usually developed to be used in a representative subset of manipulation tasks. There are two basic approaches to choosing this task subset: using a canonical set of manipulation tasks or using application-specific manipulation tasks.

Canonical Manipulation Tasks

The fundamental assumption of any task analysis is that all human interactions of a particular type are composed of the same basic tasks, which are building blocks for more complex interaction scenarios. Consequently, if 3D manipulation is divided into a number of such basic tasks, then instead of investigating the entire task space of 3D manipulation, we can design and evaluate interaction techniques only for this small subset. The results can be then extrapolated to the entire space of 3D manipulation activities. This section develops one of the possible sets of canonical manipulation tasks.

Tasks

Virtual 3D manipulation imitates, to some extent, general target acquisition and positioning movements that is performed in the real world—a combination of reaching/grabbing, moving, and orienting objects. Virtual 3D manipulation also allows users to do that which is not possible in the real world, such as making an object bigger or smaller. Therefore, the following tasks are designated as basic manipulation tasks:

Selection is the task of acquiring or identifying a particular object or subset of objects from the entire set of objects available. Sometimes it is also called a target acquisition task. The real-world counterpart of the selection task is picking up one or more objects with a hand, pointing to one or more objects, or indicating one or more objects by speech. Depending on the number of targets, distinguish between single-object selection and multiple-object selection can be distinguished.

Positioning is the task of changing the 3D position of an object. The real-world counterpart of positioning is moving an object from a starting location to a target location. Rotation is the task of changing the orientation of an object. The real-world counterpart of rotation is rotating an object from a starting orientation to a target orientation. Scaling is the task of changing the size of an object. While this task lacks a direct real-world counterpart, scaling is a common virtual manipulation for both 2D and 3D UIs. Hence, this is included as a basic manipulation task. This breakdown of the tasks is compatible with a well-known task analysis for 2D GUIs and several task analyses for VEs. Although some also include object deformation (changing the shape of an object), which is not included because 3D object deformations are often accomplished via manipulation of 3D widgets using the canonical above. Additionally, selection processes might be preceded by an exploratory task. Sometimes users explore the physical characteristics of an object (such as texture or shape) before selecting it. This may, for example, occur when an object is occluded or an interface is used eyes-off, and the actual characteristics of the object are unknown before selection.

Parameters of Canonical Tasks

For each canonical task, there are many variables that significantly affect user performance and usability. For example, in the case of a selection task, the user-manipulation strategy would differ significantly depending on the distance to the target object, the target size, the density of objects around the target, and many other factors. Some of the task variations are more prominent than others; some are stand-alone tasks that require specific interaction techniques. For example, object selections within arm's reach and out of arm's reach have been often considered two distinct tasks. Therefore, each canonical task defines a task space that includes multiple variations of the same task defined by task parameters—variables that influence user performance while accomplishing this task. Each of these parameters defines a design dimension, for which interaction techniques may or may not provide support.

Application-Specific Manipulation Tasks

The canonical tasks approach simplifies manipulation tasks to their most essential properties. Because of this simplification, however, it may fail to capture some manipulation task aspects that are application-specific. Examples of such application-specific manipulation activities include positioning of a medical probe relative to virtual 3D models of internal organs in a VR medical training application, moving the control stick of the virtual airplane in a flight simulator, and exploring the intricacies of an object's surface such as a mountain range. Obviously, in these examples, generalization of the manipulation task does not make sense—it is the minute details of the manipulation that are important to capture and replicate.

Manipulation Techniques and Input Devices

There is a close relationship between the properties of input devices that are used to capture user input and the design of interaction techniques for a manipulation task: the choice of devices often restricts which manipulation techniques can be used. Here some of the important device properties are briefly reviewed that relate to manipulation techniques. Just like input devices, visual display devices and their characteristics (supported depth cues, refresh rate, resolution, etc.) can significantly affect the design of 3D manipulation techniques. Haptic displays could also have a pronounced effect on the user performance of manipulation tasks. The input devices are intimately linked to interaction techniques for manipulation.

Control Dimensions and Integrated Control in 3D Manipulation

Two characteristics of input devices that are key in manipulation tasks are, first, the number of control dimensions (how many DOF the device can control), and second, the integration of the control dimensions (how many DOF can be controlled simultaneously with a single movement). For example, a mouse allows for 2-DOF integrated control, and magnetic trackers allow simultaneous control of both 3D position and orientation (i.e., 6-DOF integrated control). Typical game controllers, on the other hand, provide at least 4-DOF, but the control is separated—2-DOF allocated to each of two joysticks, where each has to be controlled separately.

The devices that are usually best for 3D manipulation are multiple DOF devices with integrated control of all input dimensions. Integrated control allows the user to control the 3D interface using natural, well-coordinated movements, similar to real-world manipulation, which also results in better user performance. It was found that human performance was poor in multidimensional control. The recent studies suggest that this conclusion was due mostly to the limited input device technology that was available for multiple DOF input at the time when those experiments were conducted. Indeed, the input devices that were used did not allow users to control all degrees of freedom simultaneously. For example, in one experiment, subjects were required to manipulate two separate knobs to control the 2D position of a pointer.

Some 3D manipulation techniques also rely on more than one device with multiple integrated DOF. Such techniques usually employ two handheld devices and allow the user to complete a task by coordinating her hands in either a symmetric or an asymmetric fashion. These types of techniques are referred to as bimanual interactions. The reality of real-world 3D UI development, however, is that the device choice often depends on factors besides user performance, such as cost, device availability, ease of maintenance, and targeted user population. Therefore, even though 6-DOF devices are becoming less expensive and increasingly accessible, a majority of 3D UIs are still designed for input devices with only 2-DOF, such as a mouse, or those that separate degrees of freedom, such as game controllers.

Force versus Position Control

Another key property of input devices that significantly affects the design of interaction techniques is whether the device measures position or motion of the user’s hand, as motion trackers and mice do (isomorphic control), or whether it measures the force applied by the user, as joysticks do (elastic or isometric control). In 6-DOF manipulation tasks, position control usually yields better performance than force control. Force control is usually preferable for controlling rates, such as the speed of navigation. Most 3D manipulation techniques assume that devices provide position control.

Device Placement and Form Factor in 3D Manipulation

The importance of device shape in manual control tasks has been known for a long time. Hand tools, for example, have been perfected over thousands of years, both to allow users to perform intended functions effectively and to minimize human wear and tear.

NAVIGATION

Navigation is a fundamental human task in the physical environment. The navigation tasks are faced mainly in synthetic environments: navigating the Web via a browser, navigating a complex document in a word processor, navigating through many layers of information in a spreadsheet, or navigating the virtual world of a computer game. Navigation in 3D UIs is discussed here.

Travel

Travel is the motor component of navigation—the task of moving from the current location to a new target location or moving in the desired direction. In the physical environment, travel is often a “no-brainer.” Once we formulate the goal to walk across the room and through the door, our brains can instruct our muscles to perform the correct movements to achieve that goal. However, when our travel goal cannot be achieved effectively with simple body movements (we want to travel a great distance, or we want to travel very quickly, or we want to fly), then we use vehicles (bicycles, cars, planes, etc.). All vehicles contain some interface that maps various physical movements (turning a wheel, depressing a pedal, flipping a switch) to travel.

In 3D UIs, the situation is similar: there are some 3D interfaces where simple physical motions, such as walking, can be used for travel (e.g., when head and/or body trackers are used), but this is only effective within a limited space at a very limited speed. For most travel in 3D UIs, our actions must be mapped to travel in other ways, such as through a vehicle metaphor, for example. A major difference between real-world travel in vehicles and virtual travel, however, is that 3D UIs normally provide only visual motion cues, neglecting vestibular cues—this visual-vestibular mismatch can lead to cybersickness

Interaction techniques for the task of travel are especially important for two major reasons. First, travel is easily the most common and universal interaction task in 3D interfaces. Although there are some 3D applications in which the user’s viewpoint is always stationary or where movement is automated, those are the exception rather than the rule. Second, travel (and navigation in general) often supports another task rather than being an end unto itself. Consider most 3D games: travel is used to reach locations where the user can pick up treasure, fight with enemies, or obtain critical information. Counter intuitively, the secondary nature of the travel task in these instances actually increases the need for usability of travel techniques. That is, if the user has to think about how to turn left or move forward, then he has been distracted from his primary task. Therefore, travel techniques must be intuitive—capable of becoming “second nature” to users.

Wayfinding

Wayfinding is the cognitive process of determining and following a route between an origin and a destination. It is the cognitive component of navigation—high-level thinking, planning, and decision-making related to user movement. It involves spatial understanding and planning tasks, such as determining the current location within the environment, determining a path from the current location to a goal location, and building a mental map of the environment. Real-world wayfinding has been researched extensively, with studies of aids like maps, directional signs, landmarks, and so on.

In virtual worlds, wayfinding can also be crucial. In a large, complex environment, an efficient travel technique is of no use if one has no idea where to go. Unlike travel techniques or manipulation techniques, where the computer ultimately performs the action, wayfinding techniques only support the performance of the task in the user’s mind. Clearly, travel and wayfinding are both part of the same process (navigation) and contribute towards achieving the same goals. However, from the standpoint of 3D UI design, they are generally considered to be distinct. A travel technique is necessary to perform navigation tasks, and in some small or simple environments a good travel technique may be all that is necessary. In more complex environments, wayfinding aids may also be needed. In some cases, the designer can combine techniques for travel and wayfinding into a single integrated technique, reducing the cognitive load on the user and reinforcing the user's spatial knowledge each time the technique is used. Techniques that make use of miniature environments or maps fit this description, but these techniques are not suitable for all navigation tasks.

3D Travel Tasks

There are many different reasons why a user might need to perform a 3D travel task. Understanding the various types of travel tasks is important because the usability of a particular technique often depends on the task for which it is used. Experiments based on travel "testbeds" have attempted to empirically relate task type to technique usability. Travel tasks are classified as - exploration, search and maneuvering.

Exploration

In an exploration or browsing task, the user has no explicit goal for her movement. Rather, she is browsing the environment, obtaining information about the objects and locations within the world and building up knowledge of the space. For example, the client of an architecture firm may explore the latest building design in a 3D environment. Exploration is typically used at the beginning of an interaction with an environment, serving to orient the user to the world and its features, but it may also be important in later stages. Because a user's path during exploration may be based on serendipity (seeing something in the world may cause the user to deviate from the current path), techniques to support exploration should allow continuous and direct control of viewpoint movement or at least the ability to interrupt a movement that has begun. Forcing the user to continue along the chosen path until its completion would detract from the discovery process. Of course, this must be balanced, in some applications, with the need to provide an enjoyable experience in a short amount of time. Techniques should also impose little cognitive load on users so that they can focus cognitive resources on spatial knowledge acquisition, information gathering, or other primary tasks.

To what extent should 3D UIs support exploration tasks? The answer depends on the goals of the application. In some cases, exploration is an integral component of the interaction. For example, in a 3D visualization of network traffic data, the structure and content of the environment is not known in advance, making it difficult to provide detailed wayfinding aids. The benefits of the visualization depend on how well the interface supports exploration of the data. Also, in many 3D gaming environments, exploration of unknown spaces is an important part of the entertainment value of the game. On the other hand, in a 3D interface where the focus is on performing tasks within a well-known 3D environment, the interface designer should provide more support for search tasks via goal-directed travel techniques.

Search

Search tasks involve travel to a specific goal or target location within the environment. In other words, the user in a search task knows the final location to which he wants to navigate. However, it is not necessarily the case that the user has knowledge of where that location is or how to get there from the current location. For example, a gamer may have collected all the treasure on a level, so he needs to travel to the exit. The exit may be in a part of the environment that hasn't yet been explored, or the user may have seen it previously. This leads to the distinction between a naïve search task, where the user does not know the position of the target or a path to it in advance, and a primed search task, where the user has visited the target before or has some other knowledge of its position.

Naïve search has similarities with exploration, but clues or wayfinding aids may direct the search so that it is much more limited and focused than exploration. Primed search tasks also exist on a continuum, depending on the amount of knowledge the user has of the target and the surrounding environment. A user may have visited a location before but still might have to explore the environment around his starting location before he understands how to begin traveling toward the goal. On the other hand, a user with complete survey knowledge of the environment can start at any location and immediately begin navigating directly to the target. Although the lines between these tasks are often blurry, it is still useful to make the distinction.

Many 3D UIs involve search via travel. For example, the user in an architectural walkthrough application may wish to travel to the front door to check sight lines. Techniques for this task may be more goal oriented than techniques for exploration. For example, the user may specify the final location directly on a map rather than through incremental movements. Such techniques do not apply to all situations, however. A map-based technique was quite inefficient, even for primed search tasks, when the goal locations were not explicitly represented on the map. It may be useful to combine a target-based technique with a more general technique to allow for the continuum of tasks discussed above.

Maneuvering

Maneuvering is an often-overlooked category of 3D travel. Maneuvering tasks take place in a local area and involve small, precise movements. The most common use of maneuvering is to position the viewpoint more precisely within a limited local area to perform a specific task. For example, the user needs to read some written information in the 3D environment but must position herself directly in front of the information in order to make it legible. In another scenario, the user wishes to check the positioning of an object she has been manipulating in a 3D modeling system and needs to examine it from many different angles. This task may seem trivial compared to large-scale movements through the environment, but it is precisely these small-scale movements that can cost the user precious time and cause frustration if not supported by the interface.

A designer might consider maneuvering tasks to be search tasks, because the destination is known, and therefore use the same type of travel techniques for maneuvering as for search, but this would ignore the unique requirements of maneuvering tasks. In fact, some applications may require special travel techniques solely for maneuvering. In general, travel techniques for this task should allow great precision of motion but not at the expense of speed. The best solution for maneuvering tasks may be physical motion of the user's head and body because this is efficient, precise, and natural, but not all applications include head and body tracking, and even those that do often have limited range and precision. Therefore, if close and precise work is important in application, other techniques for maneuvering, such as the object-focused travel techniques must be considered.

Additional Travel Task Characteristics

In the classification of the tasks above, they are distinguished by the user's goal for the travel task. Remember that many other characteristics of the task should be considered when choosing or designing travel techniques:

Distance to be traveled:

In a 3D UI using head or body tracking, it may be possible to accomplish short-range travel tasks using natural physical motion only. Medium-range travel requires a virtual travel technique but may not require velocity control. Long-range travel tasks should use techniques with velocity control or the ability to jump quickly between widely scattered locations.

Amount of curvature or number of turns in the path:

Travel techniques should take into account the amount of turning required in the travel task. For example, steering based on torso direction may be appropriate when turning is infrequent, but a less strenuous method, such as hand-directed steering (most users will use hand-directed steering from the hip by locking their elbows in contrast to holding up their hands), would be more comfortable when the path involves many turns.

Visibility of the target from the starting location:

Many target-based techniques depend on the availability of a target for selection. Gaze-directed steering works well when the target is visible but not when the user needs to search for the target visually while traveling.

Number of DOF required for the movement:

If the travel task requires motion only in a horizontal plane, the travel technique should not force the user to also control vertical motion. In general, terrain-following is a useful constraint in many applications.

Required accuracy of the movement:

Some travel tasks require strict adherence to a path or accurate arrival at a target location. In such cases, it's important to choose a travel technique that allows for fine control and adjustment of direction, speed, or target location. For example, map-based target selection is usually inaccurate because of the scale of the map, imprecision of hand tracking, or other factors. Travel techniques should also allow for easy error recovery (e.g., backing up if the target was overshot) if accuracy is important.

Other primary tasks that take place during travel:

Often, travel is a secondary task performed during another more important task. For example, a user may be traveling through a building model in order to count the number of windows in each room. It is especially important in such situations that the travel technique be unobtrusive, intuitive, and easily controlled.

VII. 3DUI evaluation

One of the central truths of human–computer interaction (HCI) is that even the most careful and well-informed designs can still go wrong in any number of ways. Thus, evaluation of UIs becomes critical. In fact, the reason we can provide answers to questions such as those above is that researchers have performed evaluations addressing those issues. Some of the evaluation methods that can be used for 3D UIs, metrics that help to indicate the usability of 3D UIs, distinctive characteristics of 3D UI evaluation, and guidelines for choosing evaluation methods are discussed. The evaluation should not only be performed when a design is complete, but that it should also be used as an integral part of the design process.

Evaluation has often been the missing component of research in 3D interaction. For many years, the fields of VEs and 3D UIs were so novel and the possibilities so limitless that many researchers simply focused on developing new devices, interaction techniques, and UI metaphors—exploring the design space—without taking the time to assess how good the new designs were. We must critically analyze, assess, and compare devices, interaction techniques, UIs, and applications if 3D UIs are to be used in the real world.

Purposes of Evaluation

Simply stated, evaluation is the analysis, assessment, and testing of an artifact. In UI evaluation, the artifact is the entire UI or part of it, such as a particular input device or interaction technique. The main purpose of UI evaluation is the identification of usability problems or issues, leading to changes in the UI design. In other words, design and evaluation should be performed in an iterative fashion, such that design is followed by evaluation, leading to a redesign, which can then be evaluated, and so on. The iteration ends when the UI is "good enough," based on the metrics that have been set (or, more frequently in real-world situations, when the budget runs out or the deadline arrives!). Although problem identification and redesign are the main goals of evaluation, it may also have secondary purposes. One of these is a more general understanding of the usability of a particular technique, device, or metaphor. This general understanding can lead to design guidelines, so that each new design can start from an informed position rather than from scratch. For example, we can be reasonably sure that users will not have usability problems with the selection of items from a pull-down menu in a desktop application, because the design of those menus has already gone through many evaluations and iterations. Another, more ambitious, goal of UI evaluation is the development of performance models. These models aim to predict the performance of a user on a particular task within an interface. For example, Fitts's law predicts how quickly a user will be able to position a pointer over a target area based on the distance to the target, the size of the target, and the muscle groups used in moving the pointer. Such performance models must be based on a large number of experimental trials on a wide range of generic tasks, and they are always subject to criticism (e.g., the model doesn't take an important factor into account, or the model doesn't apply to a particular type of task). Nevertheless, if a useful model can be developed, it can provide important guidance for designers.

Terminology

Some important terms must be designed for understanding 3D UI evaluation. The most important term is usability. Usability encompasses everything about an artifact and a person that affects the person's use of the artifact. Evaluation, then, measures some aspects of the usability of an interface. Usability measures (or metrics) fall into several categories, such as system performance, user task performance, and user preference. There are at least two roles that people play in a usability evaluation. A person who designs, implements, administers, or analyzes an evaluation is called an evaluator. A person who takes part in an evaluation by using the interface, performing tasks, or answering questions is called a user. In formal experimentation, a user is sometimes called a subject. Finally, evaluation methods and evaluation approaches are distinguished. Evaluation methods (or techniques) are particular steps that can be used in an evaluation. An evaluation approach, on the other hand, is a combination of methods, used in a particular sequence, to form a complete usability evaluation.

Evaluation Metrics for 3D Interfaces

Three types of metrics for 3D UIs are - system performance metrics, task performance metrics and user preference metrics.

1. System Performance Metrics

System performance refers to typical computer or graphics system performance, using metrics such as average frame rate, average latency, network delay, and optical distortion. From the interface point of view, system performance metrics are really not important in and of themselves. Rather, they are important only insofar as they affect the user's experience or tasks. For example, the frame rate probably needs to be at real-time levels before a user will feel present. Also, in a collaborative setting, task performance will likely be negatively affected if there is too much network delay.

2. Task Performance Metrics

User task performance refers to the quality of performance of specific tasks in the 3D application, such as the time to navigate to a specific location, the accuracy of object placement, or the number of errors a user makes in selecting an object from a set. Task performance metrics may also be domain-specific. For example, evaluators may want to measure student learning in an educational application or spatial awareness in a military training VE. Typically, speed (efficiency) and accuracy are the most important task performance metrics. The problem with measuring both speed and accuracy is that there is an implicit relationship between them: I can go faster but be less accurate, or I can increase my accuracy by decreasing my speed. It is assumed that for every task, there is some curve representing this speed/accuracy trade-off, and users must decide where on the curve they want to be (even if they don't do this consciously). In an evaluation, therefore, if you simply tell your subjects to do a task as quickly and precisely as possible, they will probably end up all over the curve, giving you data with a high level of variability. Therefore, it is very important that you instruct users in a very specific way if you want them to be at one end of the curve or the other. Another way to manage the trade-off is to tell users to do the task as quickly as possible one time, as accurately as possible the second time, and to balance speed and accuracy the third time. This gives you information about the trade-off curve for the particular task you're looking at.

3. User Preference Metrics

User preference refers to the subjective perception of the interface by the user (perceived ease of use, ease of learning, satisfaction, etc.). These preferences are often measured via questionnaires or interviews and may be either qualitative or quantitative. The user preference metrics generally contribute significantly to overall usability. A usable application is one whose interface does not pose any significant barriers to task completion. Often, HCI experts speak of a transparent interface—a UI that simply disappears until it feels to the user as if he is working directly on the problem rather than indirectly through an interface. UIs should be intuitive, provide good affordances (indications of their use and how they are to be used), provide good feedback, not be obtrusive, and so on. An application cannot be effective unless users are willing to use it (and this is precisely the problem with some more advanced VE applications—they provide functionality for the user to do a task, but a lack of attention to user preference keeps them from being used).

For 3D UIs in particular, presence and user comfort can be important metrics that are not usually considered in traditional UI evaluation. Presence is a crucial, but not very well understood metric for VE systems. It is the "feeling of being there"—existing in the virtual world rather than in the physical world. How can we measure presence? One method simply asks users to rate their feeling of being there on a 1 to 100 scale. Questionnaires can also be used and can contain a wide variety of questions, all designed to get at different aspects of presence. Psychophysical measures are used in controlled experiments where stimuli are manipulated and then correlated to users' ratings of presence (for example, how does the rating change when the environment is presented in mono versus stereo modes?). There are also some more objective measures. Some are physiological (how the body responds to the VE). Others might look at users' reactions to events in the VE. Tests of memory for the environment and the objects within it might give an indirect measurement of the level of presence.

Finally, if a task is known for which presence is required, we can measure users' performance on that task and infer the level of presence. There is still a great deal of debate about the definition of presence, the best ways to measure presence, and the importance of presence as a metric. The other novel user preference metric for 3D systems is user comfort. This includes several different things. The most notable and well-studied is so-called simulator sickness (because it was first noted in flight simulators). This is symptomatically similar to motion sickness and may result from mismatches in sensory information (e.g., your eyes tell your brain that you are moving, but your vestibular system tells your brain that you are not moving). There is also work on the physical aftereffects of being exposed to 3D systems. For example, if a VE mis-registers the virtual hand and the real hand (they're not at the same physical location), the user may have trouble doing precise manipulation in the real world after exposure to the virtual world. More seriously, activities like driving or walking may be impaired after extremely long exposures (1 hour or more). Finally, there are simple strains on arms/hands/eyes from the use of 3D devices. User comfort is also usually measured subjectively, using rating scales or questionnaires.

Two well-developed VE evaluation approaches

1. Testbed Evaluation Approach

This approach empirically evaluate interaction techniques outside the context of applications (i.e., within a generic context rather than within a specific application) and add the support of a framework for design and evaluation, which is summarized here. Principled, systematic design and evaluation frameworks give formalism and structure to research on interaction; they do not rely solely on experience and intuition. Formal frameworks provide us not only with a greater understanding of the advantages and disadvantages of current techniques, but also with better opportunities to create robust and well performing new techniques based on knowledge gained through evaluation. Therefore, this approach follows several important evaluation concepts, elucidated in the following sections. Figure 5.2 presents an overview of this approach.

Initial Evaluation

The first step toward formalizing the design, evaluation, and application of interaction techniques is to gain an intuitive understanding of the generic interaction tasks in which one is interested and current techniques available for the tasks. This is accomplished through experience using interaction techniques and through observation and evaluation of groups of users. These initial evaluation experiences are heavily drawn upon for the processes of building taxonomy, listing outside influences on performance, and listing performance measures. It is helpful, therefore, to gain as much experience of this type as possible so that good decisions can be made in the next phases of formalization.

Taxonomy

The next step is to establish taxonomy of interaction techniques for the interaction task being evaluated. These are technique decomposition taxonomies. For example, the task of changing an object's color might be made up of three subtasks: selecting an object, choosing a color, and applying the color. The subtask for choosing a color might have two possible technique components: changing the values of R, G, and B sliders or touching a point within a 3D color space. The subtasks and their related technique components make up taxonomy for the object coloring task.

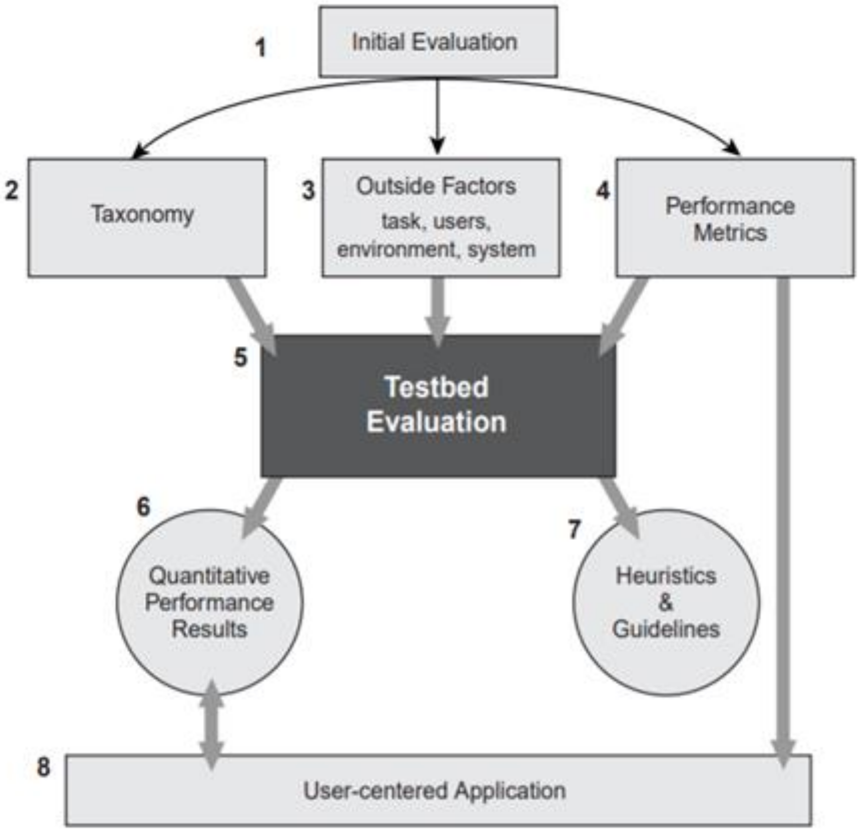

Fig. 5.2 Testbed evaluation approach

Ideally, the taxonomies established by this approach need to be correct, complete, and general. Any interaction technique that can be conceived for the task should fit within the taxonomy. Thus, subtasks will necessarily be abstract. The taxonomy will also list several possible technique components for each of the subtasks, but they do not list every conceivable component. Building taxonomies is a good way to understand the low-level makeup of interaction techniques and to formalize differences between them, but once they are in place, they can also be used in the design process. One can think of taxonomy not only as a characterization, but also as a design space. Since taxonomy breaks the task down into separable subtasks, a wide range of designs can be considered quickly, simply by trying different combinations of technique components for each of the subtasks. There is no guarantee that a given combination will make sense as a complete interaction technique, but the systematic nature of the taxonomy makes it easy to generate designs and to reject inappropriate combinations.

Outside Factors

Interaction techniques cannot be evaluated in a vacuum. A user's performance on an interaction task may depend on a variety of factors, of which the interaction technique is but one. In order for the evaluation framework to be complete, such factors must be included explicitly and used as secondary independent variables in evaluations. Bowman and Hodges identified four categories of outside factors. First, task characteristics are those attributes of the task that may affect user performance, including distance to be travelled or size of the object being manipulated. Second, the approach considers environment characteristics, such as the number of obstacles and the level of activity or motion in the VE. User characteristics, including cognitive measures such as spatial ability and physical attributes such as arm length, may also contribute to user performance. Finally, system characteristics, such as the lighting model used or the mean frame rate, may be significant.

Performance Metrics

This approach is designed to obtain information about human performance in common VE interaction tasks—but what is performance? Speed and accuracy are easy to measure, are quantitative, and are clearly important in the evaluation of interaction techniques, but there are also many other performance metrics to be considered. Thus, this approach also considers more subjective performance values, such as perceived ease of use, ease of learning, and user comfort. The choice of interaction technique could conceivably affect all of these, and they should not be discounted. Also, more than any other current computing paradigm, VEs involve the user's senses and body in the task. Thus, a focus on user-centric performance measures is essential. If an interaction technique does not make good use of human skills, or if it causes fatigue or discomfort, it will not provide overall usability despite its performance in other areas.

2. Sequential Evaluation Approach

The sequential evaluation approach is a usability engineering approach and addresses both design and evaluation of VE UIs. While some of the components are well suited for evaluation of generic interaction techniques, the complete sequential evaluation approach employs application-specific guidelines, domain-specific representative users, and application-specific user tasks to produce a usable and useful interface for a particular application. In many cases, results or lessons learned may be applied to other, similar applications (for example, VE applications with similar display or input devices, or with similar types of tasks), and in other cases (albeit less often), it is possible to abstract the results to generic cases. Sequential evaluation evolved from iteratively adapting and enhancing existing 2D and GUI usability evaluation methods. In particular, it modifies and extends specific methods to account for complex interaction techniques, nonstandard and dynamic UI components, and multimodal tasks inherent in VEs. Moreover, the adapted/extended methods both streamline the usability engineering process and provide sufficient coverage of the usability space. While the name implies that the various methods are applied in sequence, there is considerable opportunity to iterate both within a particular method as well as among methods. It is important to note that all the pieces of this approach have been used for years in GUI usability evaluations. Figure 5.3 presents the sequential evaluation approach. It allows developers to improve a VE's UI by a combination of expert-based and user-based techniques. This approach is based on sequentially performing user task analysis, heuristic (or guidelines based expert) evaluation, formative evaluation and summative evaluation, with iteration as appropriate within and among each type of evaluation. This approach leverages the results of each individual method by systematically defining and refining the VE UI in a cost-effective progression. Depending upon the nature of the application, this sequential evaluation approach may be applied in a strictly serial approach or iteratively applied many times. For example, when used to evaluate a complex command-and-control battlefield visualization application, user task analysis was followed by significant iterative use of heuristic and formative evaluation and lastly followed by a single, broad summative evaluation.

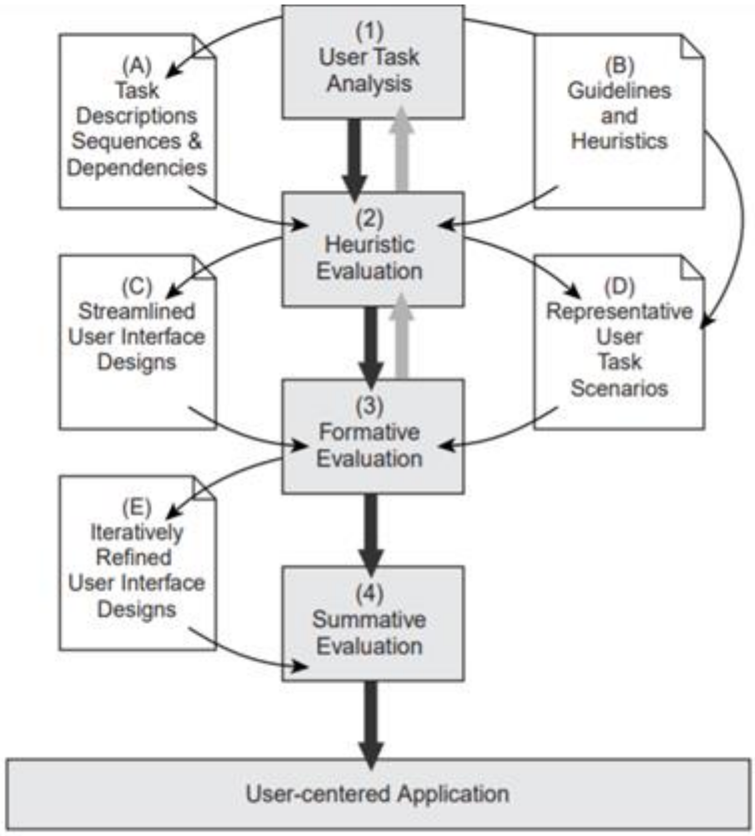

Fig. 5.3 Sequential Evaluation Approach

From experience, this sequential evaluation approach provides cost effective assessment and refinement of usability for a specific VE application. Obviously, the exact cost and benefit of a particular evaluation effort depends largely on the application's complexity and maturity. In some cases, cost can be managed by performing quick and lightweight formative evaluations (which involve users and thus are typically the most time consuming to plan and perform). Moreover, by using a "hallway methodology," user-based methods can be performed quickly and cost effectively by simply finding volunteers from within one's own organization. This approach should be used only as a last resort or in cases where the representative user class includes just about anyone. When used, care should be taken to ensure that "hallway" users provide a close representative match to the application's ultimate end users.

Following are some of the guidelines for those wishing to perform usability evaluations of 3D UIs. The first subsection presents general guidelines, and the second subsection focuses specifically on formal experimentation.

1. General Guidelines

Begin with informal evaluation.

Informal evaluation is very important, both in the process of developing an application and in doing basic interaction research. In the context of an application, informal evaluation can quickly narrow the design space and point out major flaws in the design. In basic research, informal evaluation helps you understand the task and the techniques on an intuitive level before moving on to more formal classifications and experiments.

Acknowledge and plan for the differences between traditional UI and 3D UI evaluation.

These differences must be considered when designing a study. For example, you should plan to have multiple evaluators, incorporate rest breaks into your procedure, and assess whether breaks in presence could affect your results.

Choose an evaluation approach that meets your requirements.

With respect to interaction techniques, there is no optimal usability evaluation method or approach. A range of methods should be considered, and important questions should be asked. For example, if you have designed a new interaction technique and want to refine the usability of the design before any implementation, a heuristic evaluation or cognitive walkthrough fits the bill. On the other hand, if you must choose between two input devices for a task in which a small difference in efficiency may be significant, a formal experiment may be required.

Use a wide range of metrics.

Remember that speed and accuracy alone do not equal usability. Also remember to look at learning, comfort, presence, and other metrics in order to get a complete picture of the usability of the interface

2. Guidelines for Formal Experimentation

Design experiments with general applicability.

If you're going to do formal experiments, you will be investing a large amount of time and effort, so you want the results to be as general as possible. Thus, you have to think hard about how to design tasks that are generic, performance measures to which real applications can relate, and a method for applications to easily reuse the results.

> **Use pilot studies to determine which variables should be tested in the main experiment.**

In doing formal experiments, especially testbed evaluations, you often have too many variables to actually test without an infinite supply of time and subjects. Small pilot studies can show trends that may allow you to remove certain variables because they do not appear to affect the task you're doing.

> **Look for interactions between variables—rarely will a single technique be the best in all situations.**

In most formal experiments on the usability of 3D UIs, the most interesting results have been interactions. That is, it's rarely the case that technique A is always better than technique B. Rather, technique A works well when the environment has characteristic X, and technique B works well when the environment has characteristic Y. Statistical analysis should reveal these interactions between variables.