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The Future of Computing: Exploring the Impact of 3D Technology

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Abstract

In the evolving landscape of computing, the integration of three-dimensional (3D) technology has revolutionized various industries, from entertainment to healthcare. "Computers in the 3-D World" explores the transformative impact of 3D computing, focusing on how advances in hardware and software are enabling new forms of interaction, visualization, and simulation. The study explores the key technologies behind this transformation, including virtual reality (VR), augmented reality (AR), 3D modeling, and 3D printing. It also emphasizes the increasing influence of artificial intelligence (AI) and machine learning in improving and personalizing 3D experiences. Through case studies and examples, the study demonstrates the broad applications of 3D computing in fields like gaming, architecture, medical imaging, and design, while also considering the challenges and ethical implications of this new frontier. As we move further into the 3D world, the potential for innovation is vast, and the study concludes by examining the future directions of this technological evolution, from immersive environments to the intersection of 3D computing and the metaverse.

Keywords: Metaverse, real time, intellectual property issues, physical and digital worlds, visualization

INTRODUCTION TO 3-D COMPUTING

Three-dimensional computation visualizations (3DCVs) have been seen and researched, which are computationally generated computer graphic animations showing some computational aspects of a target program [1]. 3DCVs optionally utilize a time dimension (the fourth dimension in space-time) to reflect the state of the target program at specific points of time. These dimensions help make it possible to see how 3D imagery can be used by researchers when they are the designers of computation visualizations. Most computation visualizations developed to date are static or animated two-dimensional displays. In these visualizations, two of the spatial dimensions are typically used to encode positional information (a Cartesian grid and its associated program values), and other output statistics are encoded using a range of methods such as color, intensity, etc.

Three-dimensional computation visualizations have been developed that display computational phenomena in 3D with optional time animation. The 3D computation visualizations developed fall into three categories: (1). Position and value with a third spatial dimension added for aesthetic reasons. (2). 2D views adapted to 3D, in which the third dimension encodes some other value or attribute. (3). Inherent application domain 3D views, which would include computations involving three-dimensional entities. Of these categories, it is believed that individuals using or developing research will find that category-3 is a natural fit for utilizing the 3D imagery about which observation

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was made. It is further believed that category-2 provides innovative new views of established algorithms. It is stated that when two dimensions are sufficient to portray information, adding a third can be detrimental. However, others believe that 3D imagery can also provide important cognitive cues (particularly as an aid to 3D understanding). It has been found that individuals can process information from 3D displays more quickly and just as accurately as from 2D displays. Moreover, hardware capabilities are advancing to make this type of display practical. There has been little reported research on static 3DCVs. To support the development of 3D computation visualizations, an animation methodology and toolkit/class library called Polka-3D have been created. Polka-3D does not provide a standalone 3DCV viewer; rather it is focused on supporting the development of 3D animations by programmers who do not possess an in-depth knowledge of 3D graphics techniques. Polygons are 3D objects defined in a 3D world coordinate system. Three-dimensional objects are represented on the computer using planal polygons. A planar polygon is a closed chain of vertices in 3D world space. The planar nature of the polygon object type is defined in a non-data-oriented world coordinate system. In other words, the polygons defining an individual object are all coplanar in the three-dimensional world space.

HISTORY OF 3-D GRAPHICS

Introduction of Computer Graphic 3D (three-dimensional) has occupied a larger part of our life. In the last decades we have witnessed its broad reach from ship manufacturing, product design, city design, to more mundane uses in music video, cartoons, feature movies and VRML on the web. Indeed, the immense benefit has changed the ways we visualize, convince, and communicate. Focusing on basic 3D Graphic display which is about to become popular, this study investigates the trend of this family based on the summarization [1], and aims to offer a useful guide for the 3D Graphics market. As the unquestionable advantages enumerated above, the market of 3D Graphics is just by normal logic, on its way to a rich state, which is known to all. However, its journey towards this goal is still too empirical and needs to be adjusted. A rational guideline arising from practice and theory is of great importance. Today, a variety of goods and services are provided by 3D-Graphic applications and more and more demands are required. Whether such demands will be fulfilled by the current way is in doubt. A feasible path to satisfy the demands is being sought.

KEY TECHNOLOGIES IN 3-D COMPUTING

There is a great deal of expectation about 3-D computing, virtual reality, and other applications. Development efforts have started in tracking systems, graphics workstations, simpler 3-D display systems, and 3-D interaction devices. There do exist a number of vendors such as Sony, Intergraph, and Evans and Sutherland that are in various stages of developing products. While these efforts show promise for 3-D computing on an engineer’s desktop, for the most part they are focused on simple virtual reality applications or extensions of existing computer-aided design (CAD) tools where 3-D accuracy is important. However, there are three technologies that will significantly advance 3-D computing across a broader front. These three innovative 3-D technologies that are the most significant for advancing 3-D computing are: (1) a spreadsheet-like modeling space, (2) a fully functional 3-D pointing device with force feedback, and (3) thin film electroluminescent flat panel displays with high precision digital backlights [1].

Spreadsheet-like modelers offer automatic modeling of objects and scene, a 3-D computation space, a visual programming language, a full range of rendering geometry, and image manipulations. Just as 2-D spreadsheets greatly facilitated the use of computational tools while providing a powerful creative environment for non-designers, the projection modus operandi and its subsequent copycat effect will enable the inundation of complex 3-D geometric models in various computer applications. This technology greatly decreases the modeling bottleneck and provides facile means to harness 3-D tools, freeing the vast untrained population of computer users who currently do not apply 3-D methods. Most importantly, with 3-D models of data or program visible along with modeling tools, programs or data will no longer develop in the black box paradigm now so common. The personal experience after using a CAD overlay to a spreadsheet product for the first time dramatically demonstrated how true 3-D improves understanding of CAD models. Likewise, as 3-D computational models became accessible, use of existing hardware and software improved. Virtually all areas of computing, from AI to software development and even hardware, could benefit from this technology.

It crops up that from the large number of 3D printing technologies introduced over the last 30 years only very few have become a market success. Apparently for a market success at least one technological key advantage of the new 3D printer must be combined with an attractive business concept and an astute timing. Furthermore, such a concept must include a strategy how to confront the on-going improvements in the various existing RP technologies. The timing is influenced also by the public opinion which is aroused by science fiction tales about future applications of the RP technology.

3-D Modeling Software

The advent of powerful software with 3-D visualization capabilities heralded a revolution in the desktop computer industry. Manufacturers and builders of all types of goods make use of CAD systems to create 3-D models of components and then depict the entire assembly. These models can be used in fit and function analysis. The lack of information pertaining to the methods employed to create these models prompted a search for a tool to utilize them. Possibly the most widely used system to generate 3-D models of man-made objects is the CAD system. A considerable percentage of parts manufactured today are modeled entirely in CAD and only exist in perfect data format. Most geometrical shapes are difficult or impossible to describe mathematically. Due to this fact, it is not a straightforward task to create a 3-D model from scratch. However, there are many objects that can be described or approximated easily such as boxes, blades, piping, cars, etc. These can be created from various functions that construct them, i.e. a box can be defined by the top right front and back left bottom corners. Many CAD systems offer the ability to generate models in this way. However, due to their complexity, many shapes are easier to constrain in a 2-D sketch. Few CAD systems offer a means by which a 2-D sketch can be projected onto different planes and then used as the basis of a 3-D feature. Even so, only planar 2-D sketches can be projected. Complex ruled 3-D surfaces are difficult to describe with planar sketches. Due to the prevalence of other easier ways to describe a shape, a software tool has been created that can construct a 3-D model from 2-D orthogonal silhouettes. This tool consists of a two part system: a 3-D modeling application and a DXF import utility. This system can be used by amateur or professional users.

Rendering Techniques

The hardware and software systems capable of behaviorally real-time rendering of 3-D worlds are described. Geometry is generated and shaded in real-time. Shadows, reflections and translucency are all rasterized in real-time and added to a color frame-buffer image. This is conducted with at most one rendering pass over the 3-D geometry. A platform comprising a full-parallax 3-D display and a workstation with custom graphics hardware and software renders complex 3-D worlds at update rates approaching 30 Hz. The portion of this system that functions solely on the planar underneath screen views 3-D world data. The rendering system models' emissive and Lambertian surfaces use dual rotations and projections to alter the source lighting in real-time. The real-time shading system colors surfaces based on the time-varying 3-D view and light directions. Colored transmission and reflection on surfaces with low applied surface shading detail: This is a very fast hardware-only operation, performed at over 60 Hz for the half-resolution 3-D displays. But a fast software-only embodiment is presented as well. Some complex lighting effects such as refractance, specular rendering and known-area lighting are simulated with clever texturing. The Z-buffer method is employed to successfully shadow the rasterized 3-D world and all its lighting effects. Planar reflections on the 3-D world are performed using hardware implementation of the method proposed. Possible extensions and future work are also detailed.

Animation Tools

Animation is widely recognized as a powerful technique for illustrating events that change over time. These events can be either real (a ball bouncing) or imagined (a glass of milk growing a crown of flowers). The hand-drawn or computer-generated single images are recorded on film or video and are perceived as smooth and continuous when the images are viewed in sequence. Traditionally, in 2D animation, a series of images are placed atop a sequence of clear films, referred to as cells. Each film is photographed separately to create a single composite image. In contrast, in computer-based animation each image is stored in its own file. To create the impression of movement, each image is slightly different from the others, and there will be a large file of images that can be displayed in sequence by animation software. Although the quality of computer-based two-dimensional products has reached excellence, the commercial industry is prolific with them, and it is utterly hard to compete. Alternative yet less common methods to achieve that are the use of mesh sculpting or painting applications. Computer-generated 3D models can be generated from scratch within the animation software or import. However, those tasks require a substantial amount of time, expertise, pain, and also the use of non-traditional art skills.

The refinement of accessible three-dimensional software with simplified interfaces and tools for users unfamiliar with art and rendering aspects has created a strong push towards the adoption of these tools for open artistic and research challenges. In the scope of these challenges, much civil research work has been accomplished to foster the development of easy-to-use tools and approaches in 3D manipulation, including mesh sculpting, painting, and reading of 3D models. Despite an interest has been growing for these topics in recent years, the development of accessible 3D tools, applications, and services for character and facial animation has been left behind 3D manipulation and Creativity Animation. Nonetheless, the need to address animated 3D challenges suits several types of creativity, expressive, multifaceted 3D authoring, reading of fine 3D geometries, and 3D emotion understanding, among others [2].

APPLICATIONS OF 3-D COMPUTING

Three-dimensional (3D) imaging has been a continuing area of interest in visualization research for many years. However, only recently has the necessary hardware begun to reach the point where detailed and interesting 3D graphics are practical. There are now a number of architectural systems coming on the market which provide the rendering power to display intricate 3D imagery [1]. The question of how to use this power to provide useful 3D displays or interactions is largely open. One possible direction is the development of 3D computation and interdisciplinary research which is currently being explored in the field of young visualization. To help stimulate further research in this area, the potentials of 3D computation have been observed or implemented. The initial steps toward such 3D computation visualization have been implemented in a 2D environment, encoding 3D information through use of color, shape or motion. Research and emerging standards of 3D computational capabilities have been developed which begin to support more direct 3D visualization of computations [3].

In addition to the usual computer graphics and imaging equipment, programs can be viewed in a 3D room containing many fixed lights and grayscale screens, and user interface devices with a head-tracked stereo image. Information appears to float in air. Such a system is useful for 3D visualization creation, viewing, and editing experiments. Professional programmers who specialize in the production of 3D animations are immediately confronted with a virtual thicket of acronyms and technical terms. When speaking with these people, they have a specific short-term goal rather than an open-ended question. Finally, a 3D accelerator board, a 3D program and a 3D model are highly recommended for attempting to verify the following as an appropriate 3D file format.

Gaming Industry

The gaming industry is nearly a $ 10 billion a year industry, with both video game and arcade sections. Recently however, the financial instability of traditional arcades has been growing larger and more insistent. Analysts have been expressing concern, particularly with exits by industry giants. Still, a few carefully chosen members of the industry are attending to competition in a manner beyond opening new facilities or capitalizing on the latest profitable technology.

The name above the door is Steven Spielberg, and the featured product is Activity Annex. The venue, and the plan for dozens of others like it, is GameWorks. Like the other ventures, GameWorks seeks to provide more than mere video screen games. The facility boasts 200 arcade and video games, as well as simulation rides and skill games. However, a variety of other traditional arcade experiences form the core of GameWorks business along with restaurants and party rooms rented in one-hour increments. The system of tokens has been replaced with wireless debit cards. The games are proprietary, with new ones available only at GameWorks outlets. Players enter to metal detectors and occupied by a giant, four-foot-wide version of select games. The informational video closed by panning across hushed rows of demonstrators, silently doing battle with the newest weapons of the amusement industry.

Film and Animation

The author accepts the hypothesis that digital media assumes a self-contained communicative system that blends visual representation into the wider circles of technology, neurology, and genetic code, where the psychological aspect of representation is considered of higher importance than the cultural aspect. It is proposed that the collision of these three distinctive disciplines in the fields of networking, DNA-based biocomputing and nanotechnology recommends the wider reconsideration of the subject of computing. This has always been a broad field of research, but its examination through the window of 3D graphics generates an especially wide panorama. But the subject is not just 3D visual entertainment; it is visual simulation of artificial objects, handmade or scanned, mostly for further industrially standardized treatment. No question may arise about the broad range of specific uses of 3D graphics; they mushroom in almost all sorts of distinct businesses and fields of study, being engaged as a medium of aesthetic representation, a construction plan, a digitalization tool, a prototyping aid, and even, following the creative engineering demands, as a mode for bentlog or voxels representation [4]. However, the objection that very often the digital intermediate is just a phase in the technological flow, having no intention for an obscure artistic anymore, does not blunt the argument about the lack of any classic glossy garlands granted at the consumer end, like in the case of the fourth generation masterpiece, as it was in the event of the two-dimensional exhilaration. In that particular field, the proposal argues that visual communication would be rudely incomplete without the 3D realization, while noticing that only a handful of the most technically advanced players remained highly placed in the spectacle pecking order. Punchier conclusions about the visual representation of communication intertwinement with 3D lines offer the cinematic and virtual-animation applications, as they have special connection to the different context of national film industry.

Architectural Visualization

The availability of powerful computers, the advancement in software dedicated to various aspects of modeling and visualization of architectural objects, as well as an increasing interest of architects themselves in modern technology and opportunities it provides, has brought major changes in modern architectural work. Computers have become an essential tool in architectural design at the stage of preparing the architectural concept, technical drawing and detailed design presentation. Today, construction and architectural companies computerize their work and prepare models, visualizations and projects of facilities in the newly established three-dimensional space. This applies to new areas of architectural creation in virtual reality. From the point of view of a professional architect, an essential feature of this type of architecture is the possibility of presenting an object in the 3D digital form that allows its virtual moving and manipulation. It also involves changes in the conventional form of presenting architectural ideas such as drawing and visualization of projects or object models. The three-dimensional visualization of architectural objects in new ways of presentation in the digitized space is of considerable efficiency in the process of shaping facilities' appearance [5]. Such visualizations are not only propaedeutic, they also play an increasingly large role in the advertising process.

They allow potential clients not only to become acquainted with the appearance of a newly designed facility, but also to move around in the space and amongst it. Also, the gallery of visualization may be used as an introduction of a building fire alarm system or a warehouse arrangement. When video is composed of a series of images, thanks to the possibility of manipulation in the digitized space, the development of a moving of a camera around or in an object is possible. Digital video reflects reality more than 3D objects and offers the possibility of breathing life into presentation, in the form of placing characters in situations or surrounding. Such methods of animation of digital projects are widely used in adverts and website presentations. There is a growing number of websites, to which architectural companies transfer their accounts or in the form of digital models, visualizations, animations, giving the opportunity of accurate evaluation of achievements.

Architecture is a discipline marked by its ability to express itself into traditional representation, where artists, architects and drawings have always been in the spotlight. It is also an academic education where the artist comes first as a mandatory step for architecture. This means that business nourishes itself with graphical objects and that it is graphic content that builds the backbone of architectural and urban projects. At the same time, architectural practice feeds on graphic representation as a narrative and critical medium to develop, edit and even defend its work. Since overtaking manuscript and photography into the architectural disciplinary field, as media tools of graphic representation, the last major technological breakthrough has been the advent of computer and videographic editing in the 3-D world.

Medical Imaging

Medical visualization includes the use of various techniques to image the structure/anatomy and function/pharmacology of human bodies. Wide spread of such techniques is referred to as Medical Imaging. This overview presents different techniques used to create medical images and the techniques used to visualize those images. The section is organized as follows: First, it will present a brief overview of viewing medical images, possible sources of medical imaging data, and different techniques to create medical images. Then it will overview different types of medical images and related volumes commonly used to store them. Lastly, it will discuss a number of approaches to visualize the information represented by the volumes. Possible projection methods to create 2D images as visuals will be described and 3D mesh will be used to describe methods of volume reconstruction and surface extraction. Regular clinical methods to create images of 3D structure inside the human body include Computed Tomography (CT), Structural Magnetic Resonance Imaging (MRI), Endoscopy and more recently developed different tomographic techniques for monitoring radiation during its administration. Projected images of the surface of the human body or of its cavities can be produced by photography and X-Rays (applied either on surface or with above-mentioned methods). These days Digital Reconstructed Radiograph is being used to virtually constrain the projected anatomy for position verification during radiation treatment for patients with tumor. Ultrasound Image (called US here) is a further possibility to produce 2D structural image [6]. These above-listed ways to create images of 3D structures inside and on the human body will be discussed.

3-D PRINTING AND PROTOTYPING

Among the many pedagogical considerations currently being given to the consolidation of 3-D technologies within education, an additional one should be the ways in which they might inspire a next generation of makers, boosting recipients to transition from mere consumers of goods or services to truly innovative producers of goods, tools, and structures. 3-D printing and all its upcoming relatives and offshoots hold that within close reach, providing an indispensable toolset with which an unlimited diet of cabinet-of-curiosity-style ephemera can be engendered [7]. 3-D printing is now within reach for most education institutions and is incrementally common in enlightened labs and classrooms, therein, it is possibly encouraging to explain and exemplify some of the easiest entry points into the field.

As a more complicated example, mechanical 3-D modeling techniques are described for making things such as pinhole cameras and planetary gears. However, the depth to which various techniques are covered is kept to a level that should be achievable by anyone burdened with, or gleefully bored by, the task of teaching teenagers. As applied research group’s online resources and as well as the worldwide 3-D printing community are capable to providing the 3-D models necessary to realize many of the projects outlined in this study or indeed to develop and share whole new ones. Indeed, schools and universities typically engaged in the training of early-career researchers and technicians must not be under the impression they are permitted to proceed into the 3-D printing era as mere recipients of fabulous, lab-grown factotum. Instead, running large workshops and education departments should join the nebulous role of facilitating a wider introduction to 3-D printing and closely related design and fabrication technologies [8]. At the very least they are expected to establish the requisite infrastructural support to afford more students and educators alike easy and direct access to 3-D printing and related technologies. Conversely teachers, technicians and students should be empowered, through talks, workshops, online video resources and other means, to export and replicate successful elements of their 3-D adventures at other participating labs.

Overview of 3-D Printing

Additive manufacturing, more commonly known as three-dimensional (3-D) printing, refers to a family of technologies for making parts by creating cross-sectional layers of a material. 3-D printing began in 2010. At that time, the technology was widely seen as something used mostly by hobbyists. By 2011, the mainstream news media was reporting that 3-D printers could be acquired for the cost of a basic laptop. A poll the same year reported that nearly 40% of the population would consider buying a 3-D printer. Today, 4 years later, 3-D printers are beginning to come pre-installed in consumer's homes. Items can be printed out at the push of a button [9].

This technology has wondrous applications, and it seemed there was no limit to what could practically be printed out. The resolutely unimaginative raided internet catalogs. Those with a love for art began acquiring complex figurines and sculptures. These, however, would soon be looked upon as the earliest examples of a dying industry. Commerce would no longer tolerate manufacturing restrictions. The true future, instead, would belong to printable buzz toys and the makers. At present, its use would become most apparent in how it radically changed existing business models. Widespread piracy was creating a crisis in the entertainment industry, but curiously, the planners were never credited with hitting that particular nail on the head. Far more importantly, near-ubiquitous recycling of raw materials was rapidly making poverty history. Even this would pale in comparison to its effects on the "Ancient Economy", the intellectual struggles itself pushing business models to a breaking point.

Materials Used in 3-D Printing

In the 1990s, researcher groups around the world started to work on the rapid development of this technology, in the material of processing and in the introduction of new materials as feedstock. Some of the materials used by 3-D printing are polymer composites, metals and alloys, powdered glasses, sand paper powders and powdered ceramics. However, some of them have a disadvantage that the material properties are not always homogeneous or adjustable. This group proposed the development of a novel feedstock material for 3-D printers, based on thermoplastic pellets. Pellets have the advantage of being pure and homogeneous material, and at the same time they are available in a wide variety. This versatility allows the development of a large variety of composite materials, taking advantage of the simple setup of the 3-D printer process. Moreover, thermoplastic pellets are recyclable material, and the unprocessed material can be reused several times after the cleaning process [10]. Three-dimensional printing is a fast and cost-effective option for prototyping on a broad array of materials, including resins, which is used to make parts in medicine, engineering, design and art. However, the printing of a cylinder forms constraints and challenges on the techniques applied with the polymer resins for realizing accurately curved surfaces, the material properties after post processing and the achievable resolution of printed layers. A systematic study of the printing Z-axis orientation, post-processing and the layer thickness effect on the final part with respect to the accuracy and resolution. The results showed that the accuracy is inversely proportional to post-processing time and layer thickness and directly to Z-walls orientation; the resolution is proportional to the post-processing time compromising; however the accuracy of the parts and that the highest resolution achievable smoothening acetone vapor treatment and baking is two and five times lower comparatively, respectively when smoothening it with primer or vapor treatment.

Three-dimensional printing has rapidly established itself on the rapid prototyping and advanced manufacturing fields. The ability to print geometrically complex objects has also enabled researchers and lay persons and many new fields, including the very nascent 4D printing, where a printed object changes shape after fabrication. Interestingly, the high precision and programmability of 3D printers can be used as safety-override devices on a wide range of industrial machinery. Modifying a 3D printer on the 3D ball-printing platform can demonstrate the destruction of plastic encased consumer electronics and it disables the shredder meant to destroy them, allowing the extraction of embedded data storage chips. In light of these observations, owners of sensitive electronics may ascertain for themselves the assurance of data security by printing and adhering to customized debris containment objects. Modern times have evidenced critical asset leakages in the consumer electronics disposal and dismantling industries that were facilitated by a lack of physical security over the shredded waste. To alleviate this, a novel method was employed for desktop 3D ball printers to render hard-sealed electronic housings easy to access.

Applications in Various Industries

Applications in various industries decided to use computer graphics in their manufacturing plants for new product design. Architectural firms use computer graphics to give prospective clients an idea of the proposed surroundings, shops and buildings. The use of computer graphics in the mining industry is not very widespread. Certain shafts use computer graphics for various mappings of the mines and as a few geological applications. The biggest user of computer graphics is the gas and oil industry for geological mapping of particular locations. Hand held computer graphic capabilities were investigated. Computers were used for display on a drum plotter, storing up to 200 vectors per view. In all instances a viewer was used to give a 3D effect. In the gas/oil industry the viewer was adapted to the raster lines. An industry generally deals with vast amounts of information (both graphical and textural). The two must be used in unison. When you review any information, the normal process is to lay out all the drawings and information in order to refer to the right data. An interactive computer graphics system would greatly enhance decision-making. The need is for a video display system that can display a 2D drawing which can be interrogated with a light pen.

One of the workable systems looked at was a display system, now superseded by another model. Working with Vector Data, it was found that certain systems would be more ideally suited. A system would require a particular software, which is not currently available. Another option is the use of equipment which hooks on to a mainframe. As a company is in the process of introducing new equipment it was mutually agreed that the simulation would be done using graphic systems. Each different application in industry would require its own programs. Before the modeling of an item could even be contemplated, a method would be required to transfer the data to the computer system. Where items are not too complex, a 3D-light pen could be used in conjunction with the graphic system. The processed data was then used as input to the system where area and volume calculations were made. Compliance with specific safety standards also seems to be a problem. The department of industries actually specifies that: baffle angles for derricks should be greater than 45° for easy access. So, programs can be written to impose this ruling and computer graphics enters a new dimension-specifications checking. Particular potential users of this system could be the electrical, chemical, civil, and naval industries.

VIRTUAL REALITY AND AUGMENTED REALITY

We see the world in three dimensions (3D) because we have binocular vision, that is, each of our eyes sees an image with a slightly different perspective. The brain synthesizes the two separate 2D images into one 3D mental picture. The first device that produced these 3D effects was the reflecting mirror stereoscope, invented in the 1830s by Charles Wheatstone. However, the two 2D images are still distinct; i.e., if an object is supported by a person's left eye in the scene on the left, it cannot be seen in the other. This problem was later resolved by red-blue anaglyph stereoscopy [11]. Conceptually, Virtual Reality (VR) was first described by computing pioneer Sutherland, who, in 1968, envisioned a computer-generated "ultimate display" that would engage all the senses. In 1969, with the help of his student, he created the first VR head-mounted display (HMD) system, also the first 3D graphical interface. Not long after, Myron Krueger invented the first virtual reality art installation, transforming an entire room into an interface. However, comparable computing power was then scarce and Avatar lacked a user-friendly GUI. This frustration led to Lanier's creation of the DataGlove system from the 1970s prototypes. The actual term Virtual Reality was coined in the 1980s, when Jaron Lanier's Visual Programming Lab began producing the first commercially available VR headsets and gloves, paving the way for the development of simulators and scientific instruments. Since then, efforts to seamlessly integrate the human body into the virtual experience have driven significant advances in VR and Augmented Reality (AR) human-computer interfaces (HCIs) [12]. One of the first widely implemented large-scale full-body interaction systems was the CAVE: a room-sized interface consisting of four 10-ft screens. Inside this three-walled room, users wear Liquid-Crystal Display (LCD) shutter glasses and a head tracker and interact with objects using a wand-like device. Although comparable setups are expensive, scaling down the CAVE paradigm and expanding Powerwall technology has enabled researchers and artists to create and experiment with VR environments. Power walls and CAVEs are particularly attractive as collaborative environments for discussing and manipulating VR objects, especially as 3D printing solutions are added. Nonetheless, a number of technical, physiological, and psychological issues must be addressed to make VR as seamless, nonintrusive, and functional as described in popular science fiction. With the advent of Mars Exploration Rover missions, in 2004 a number of researchers used the driver's seat of a car as a Mixed or Augmented Reality telepresence environment. Until recently, however, VR was mainly considered a "dead technology". On the one hand, while a number of major technology companies invested vast resources into VR development in the 1990s, the technology was still at its infancy and nascent World Wide Web-dominated business did not see immediate profits and abandoned the field. After the "dot-com bubble" burst in 2000, more and more technology companies halted all research and development unproductive and unrelated to their core business ideas (acting primarily out of self-interest instead of a genuine commitment to advance technology).

Difference Between VR and AR

Advances in computational power hardware and especially graphics processing units have made cutting-edge graphical advancements allowing modern computers to render nearly photorealistic photographs in real-time. The progress of this technology and their companion fields has made feasible to implement such great advancements for 3-D worlds virtual reality (VR) or augmented reality (AR) environments.

VR artificially encapsulates its user inside a 3-D space or world. In its most basic form, a monoscopic desktop program that renders 3-D object models on the screen has been in use for many years. Recently, 3-D VR has experienced a resurgence; the 3-D glasses games with Nintendo systems and the Hardlight VR exhibit show this. There is an increase in effort within the development of VR. More expensive full systems becoming available have been used by technology companies for the development of consumer and research software. When one enters a VR space, they generally wear a typically overpriced headpiece that contains two tiny radios and (quite possibly) an emissive eye display. In this headset, each screen facing the eye creates the viewpoint of a simulated pixelated 3-D world. The amount of picture displayed changes as the person passes the head around in order to create the illusion of space. Cameras are able to observe the environment with objects to be interacted and a storage device is utilized to record extra dimensional information about space that allows the inclusion of corresponding objects in the program. A phenomena detector subsequently informs the device of possible collisions with the measured environment and will prevent anything from damage. Variety of input devices are implemented such as the glove's system that is equipped with pressurized tubes designed to mechanically restrict hand movement. Alternative input devices are gloves with lights that allow for hand-tracking utilizing infrared cameras or a single three-dimensional camera mounted on a handpiece that looks like a third-person game camera system on a flexible extension stick. The base station emits non-lethal high-frequency waves that stimulate the brain and create motion sickness to limit playtime [12]. With AR, a 3-D world cannot be encapsulated by its definition and, as such, the user remains present within their own 3-D environment. If VR can be defined as utilizing a 3-D world or digital space, it only stands that AR is the opposite; as such, the environment is enhanced using digital data. This has the potential to take many forms, but the most interesting and optimal usage of this definition is wearables that project light or a display which blends virtual light with the ambient physical light [13]. Also critical to the AR experience, these devices are imbued with the Raspberry Pi Model B+ microcontroller which is important technology because it is impossible to achieve full immersion in a market-approved AR system unless it routinely stalls or crashes. This means the system has the capability to match the performance of a cutting edge device produced 6 years ago. The total-state technology accumulation ensures that third-party software available in 2014 has the potential to be run on top-of-the-line consumer hardware.

Impact on Gaming and Training

As video games have become more realistic, so has the use of three-dimensional worlds in many different applications other than just gaming. These three-dimensional worlds also known as virtual realities can be constructed on the computer and displayed on a 2D monitor. To fully experience the virtual environment in front of them, stereoscopic glasses can be worn. Research is being done on how these virtual realities, properly designed, can provide better training environments for the automotive and aerospace industry. Good visual simulation can go a long way to provide a realistic view of the design. To study this better a program called Finite Element Analysis is used to study the stresses and deformation in components under loading conditions. Though a lot of information can be distilled through this program, the results are only shown as numbers, graphs, and deformations in 2D. The tolerance and ease of assembly are all important factors in the design of mechanical components. To reduce weight and remove unnecessary stress, holes are often drilled in areas where the stress is very low. Though drilled holes have a better stress concentration, often other features such as cut-outs are made due to other design parameters. To cope with stress, thicknesses of the material are often changed, smoother fillets are used, corners are radiused and sometimes shapes are extruded or reduced in size to the components. All of these design features however can lead to assembly problems as well as tolerance problems. Executing the assembly, rostrums models are harder to interpret and do not provide as good view as the actual part. Fluorescent penetrant and X-rays however have their own limitations. Virtual Reality technology and the virtual prototyping of mechanical assembly is one of the important research topics. So, as of right now, there are systems that allow the user to see a more realistic representation of the components and shows an animation of the assembly but does not provide the tolerance of the parts and does not take into consideration the ease of assembly.

Desktop computers based virtual training systems are attracting attention from manufacturing industries as they offer possibility for cost-saving over conventional training practices [14]. The most apparent advantages of desktop systems are the significant cost savings that can be realized due to shorter training-scenarios development times and the re-use of existing engineering models. Additionally, due to the non-necessity of assembling hardware parts, a significant reduction in the time between the conceptual end of a product and the start of commercial production may be achieved. The ability to produce realistic sound, visualization and simulation is proposed to develop haptic feedback system, with the goal of providing in real-time accurate tools; object-material graphics and simulation interactively manipulate in 3D dynamic virtual worlds. Configuring assembly instructions when performing assembly tasks in sustaining a productivity tool time-cost paradigm analysis for real world training is an adaptive-genetic programming methodology applied to function approximation.

Future Prospects

Research would target the delivery of small, high-resolution light field displays resembling tablet or laptop screens in terms of size and practicality. The natural extension would be to develop wall-sized displays with even larger view frustums for the ultimate immersive 3D experience. Although envisioned in the future, futuristic reflectors would eliminate the need for displays. Instead of devices being needed to provide 3D information they would receive it, and hope to see smart-glasses that translate multi-view 3D content to light sliders linked to a user's position. In a similar vein, integral color holography would provide full diffraction 3D experiences. Smart clothing would emit light fields for full body sampling. Instead, vehicles, street furniture, and lamps would generate light fields, thereby overcoming occlusion. The ideas of reflectors and smart clothing are not within the reach of current research and so applications to mid-far future technologies are not discussed.

The viewing experience is greatly affected by display artefacts as viewing conditions can be poor. An ultimate LFD user experience would account for incorrect viewing conditions all the time, such as global lighting and accurate display tilt. The research direction is how LFD users obtain high-quality images even when viewing from incorrect positions. An LFD display illuminates a scene with geometric effect known as the relief effect, which can be seen when looking directly into the display. Novel optics can greatly reduce, or eliminate, the relief effect when viewing from unauthorized directions [15]. This could be realized through optics on a cellphone cover or by producing a higher than needed image before down-filtering for a crisper view. There will be a growing demand for fast prototypes of software applications as 3D content expands. A view-based company would prototype a wide range of 3D content ideas which would involve multi-view autostereoscopic screens. To prevent idea theft and encourage companies to opt from a certain perspective, prototype images would be encrypted and only decryptable from a certain viewing position. It would be valuable to investigate how to take advantage of the relief effect and develop private control methods based on such an effect.

CHALLENGES IN 3-D COMPUTING

In the 10 years since their introduction, graphics workstations have revolutionized 3-D computing. Although the numerical representation of solid objects in computers is handled quite differently in the two areas, the solid modeling community is likely to be affected far more radically than computer graphics. This is because solid models often require far more data than is needed for a reasonable view of a solid object. However, even from the computer graphics viewpoint, some repercussions are apparent. The display of models with millions of polygons is a problem not addressed by commercial OEMs to date. And the relatively recent growth of the latter's capacity for pushing polygons leads to some undesirable consequences for the graphics profession. At present, CAD/CAM drawn view standard presentations are usually flat shaded or smooth shaded IRIS-checker images. Viewed from any other direction, the model is shown using lines or hidden line removal. Since the computer industry customarily shows its wares in the flat shaded mode, this has become the preferred CAD display style, regardless of the fact that it is the most sensitive to the detail of the model and hence the way to most accurately show how a finished part would look. Commercial demonstration software has exploited the opportunity to enhance an object's appearance in such a way that non-IRIS equipment is inadequate to the task. Conversely, looking at something that is merely flat shaded may generate a misconception of its quality even if all the important detail is present.

The ability to accept polygons directly creates a technical expectation of their use. This might precipitate the emergence of databases and file formats that are polygon based rather than more expert oriented. Similarly, there has to be some form of polygonal representation of a model for the checked lines. If the model has not been polygonised, the graphics system will perform the calculation every time the model is drawn. For a model containing 10,000 polygons, the time taken can be substantial. In complex, quasi-random objects, the rendering of a single checked line image can take 50 sec or more. This not only affects the speed of real-time interface, but also makes it virtually impossible to have the system generate the images for the demonstration video document. The press publications concerning NCGA can also serve to foster an impression of reality that is quite misleading, particularly in areas like the display of models constituted from near-contiguously joined clipping models.

Hardware Limitations

Limitations arise with the implementation: as with many technologies, expectations and reality often do not coincide. The representation of text definitions, text documents, terrain and so forth, as 3D objects looks promising, but once this needs to be implemented, real world problems arise. This was one conclusion drawn during the development of the 3D Bitmap System (3DBS) [16]. There, zeros of scalar functions (and to a limited extent their corresponding level curves) as they arise in 2D text document must be represented in a 3D environment. This procedure is non-trivial. Some results: The representation had to be rather crude to avoid display-time delays; otherwise processing a short text document (a couple of pages, say) would have taken periods of time unacceptably long. There is a significant time delay between the creation of the 3D environment based on user data required by the system and the actual representation of the object. Due to the extensive real-time interaction necessary between creation, optimization and volume rendering, any 3D environment is unworkable on a current PC for large data sets (for example, anything larger than 20×20×20 voxels).

Software Compatibility

All hardware devices, named and unnamed, like professional graphic system and software products under the marketplace, can be declared as pictures, alphabets and data lists, defined by traditional standpoint. But the market has raised into a high-tech and hi-cost competition, where hundreds of leading-edge companies slash and design new products and beyond-the-times. Japan has become a success on the Video Robot (live robot) through the efforts and cautious steps with several compromises at the competition between USA and Japan. To reach the advanced hardware products, it will spend much time and cost unless software components are readily available. The cost effective and time saving product is offered and combined with major results of research on computer graphic systems that are compatible with any hardware, also recommended for software application experts.

Computers and computer graphics are playing more important roles each year in today's highly technical world. Undoubtedly, one of the major factors has been the declining costs of system hardware and software. It is apparent now that with each passing quarter, prices of graphic display systems are continuing to decline even as system performance specifications increase. It is expected that this trend will continue and even accelerate as more manufacturers enter the graphic display system market. Unfortunately, this creates a dependency between graphic software products and hardware equipment. Graphic software has always been dependent upon and must be designed specifically for a particular type of display hardware [17]. For example, a Sony monitor requires software packages designing in such a way that data delivered to the system must be in the form compatible with Sony display system. On the other hand, a calculated software system recently developed will not work properly with Sony equipment since it displays simple black and white line graphs. Any attempt to use different equipment and software components will cause only the output of pictures that have no value at all. This therefore presents a difficult problem for all software consumers.

User Experience Issues

The user experience (UE) issues centered on the usability and interaction techniques of the VirtualCAD environment in VE, and VRML and CAD interfaces enhanced with additional navigational and haptic interfaces. The relevance of the studies to UE issues described above is also presented. The earlier usability study investigated traditional CAD in traditional ‘monoscopic’ computer environment using assistive force feedback interface and compared it with the virtual stereotype of prototype design developed for VE, according to the low-fidelity and high-fidelity approaches. The frameworks for investigating UE issues in VE not only in the context of VirtualCAD systems, but also in VE experiences in broader terms are mostly review.

Functionality evaluation studies of multimodal interfaces are conducted, because UE issues in VE are closely related to the effectiveness of different forms of interaction techniques, such as cognitive and perceptual processing load, different computing and physical interface devices, types of feedbacks.

The experiments assess the impact of various navigational modes on the user perception during travel in VE. The results of research studies lead to the development of a number of evaluation methods for the 'usability is naturalness and ease of use' issues not only in the context of traditional desktop computer environment, but in VE settings [18].

In the most recent usability studies, the additional evaluations are conducted to explore UE issues in terms of (a) ways of providing within-interface elements that support and enhance the spatial orientation, affecting the sense of immersion and presence as well as contributing to the reduction of the motion sickness induced by unnatural travel in VE; (b) ways of mapping travel direction to navigational commands in VE; and (c) ways of manipulating objects in 3D space in VE. The effects of traditional desktop interact to academic level on UE issues in CAD applications. This leads to the development of number of user guidelines for the creation of more usable interfaces in CAD; however, it is recognized that the issue of UE design of inclusive interfaces in VE is 'not well understood and still in state of evolution'. As a result, the commonly quoted researchers conducted the only laboratory studies 'either physiological or response time measures' to evaluate UI issues in VE. These often included various VR testbed evaluations of only the most basic navigation techniques in simplest of rendering arena devoid of objects or strong constrictions placed on locomotion. More directly, related to UE issues, however only the perception of the 3D objects from user viewpoint is done. This multi-site study also presents the critique for not using 'double blind' procedure 'to maintain the scientific rigor of the study' like the stereotype experiment of low-fidelity design. More broadly, the closer electric field of enquiry informs later review of 'what investigation is most relevant to UE issues'.

FUTURE TRENDS IN 3-D COMPUTING

The world is moving towards the ultimate goal of three dimensional (3-D) marketplace within the next 5 years. A digital (3-D) environment can be obtained through use of stereo displays or other "virtual reality" devices. With these environments, when one refers to computers, one implies all the necessary hardware that will be built into the system. Computer hardware will assume the form of smart skins, with computational power distributed entirely over the surfaces of objects [19]. Software will not be left totally to the computers. Instead, software is in the form of "cons" or "anti-viruses", and they too pervade the 3-D environment. The current 3-D applications include various 3-D game machines and helmet with 3-D display and motion tracking mouse. Potential 3-D intranet environments with a high total value professional multimedia design have been implemented. There is also brief mention of some different 3-D research being carried out by using goggles with multiple interlocked zones on the lenses. Other 3-D software research includes a new simple FFT 2-D texture resampling technique, and the development of an alternative way to use the AutoCAD 3DMF rendering engine to produce heels and specials. All three presentations emphasize that the 3-D future might still be at least 5 years away. This is mainly due to the enormous amount of investment still needed to produce a wide range of economical 3-D display technologies with the necessary higher resolution. The ultimate dream of 3-D will be digitally encrypted objects combined with virtual reality environments obtained using goggles and wired data gloves. With the coming of Windows 95 and the Internet, it is anticipated that there will be an enormous amount of "hype" about 3-D market places. It is expected there will be some form of 3-D web browser similar to VRML. It is more likely that smart natural shapes will have an extremely high value placed on them. The 3-D marketplace may affect the future of professional styling and the development of CAD/CAM systems.

Machine Learning and AI in 3-D

English words generally have a consistent mapping between how they are written and how they are pronounced. In contrast, the admiration of the letters G, H, and I in that order is fairly independent of their spatial arrangement within the word. Different visual features can be relatively more or less informative, depending on the domain. Letter case is not diagnostic of meaning, while letter position is critical for specifying meaning in most English words. These examples illustrate a broader point that basic tasks like object recognition unfold differently across different input modalities and data generating procedures. People in each domain use different representations of the data and different procedures to analyze that data [20]. This suggests that if, or when, 3-D data reaches a critical mass, people may develop new mental representations and new cognitive procedures to understand and interact with that data. It also presents a conundrum for the challenge of machine learning and artificial intelligence. The same methods that work so well in one domain may not be immediately transferable to another domain, let alone to all computational problems that matter.

Most of what we know about vision, in computational terms, boils down to solving the inverse problem of recovering properties of the world from 2-D projections, where a typical scene corresponds to countless plausible 3-D interpretations. A wide range of solutions have been proposed for this under-constrained problem, including exploiting binocular disparity, motion parallax, and shading. But a more general class of solutions is structural: The world is composed of a set of simple shapes that are combined according to a set of rules. For a sphere, the structure is its radius, and there is a single deep rule that all points on its surface are a fixed distance from its center. This formalist notion of geometry has a long lineage in philosophy and is one foundation for computer graphics.

Real-time Rendering Advances

Computers in the 3-D World: 3-D Graphics

Although not a new technology, real-time looped refinements in the rendering of 3-D graphics represent significant advances. Computer scientists have investigated the cortical rendering of dynamic representations of 3-D space and motion with an emphasis on real-time displays on workstations and high-performance personal computers. Such refinements involve progressive enhancements of hidden-surface removal and antialiasing, obtaining greater realism through the addition of reflections and refractions, and improvements in the representation of the illumination model [21]. For some systems the leap to real-time enhances interactive query and control, and these in turn have implications for engineering and artistic design.

An issue of greater concern is the user interface to the 3-D world. While a dynamic 3-D representation is gratifying, the ARRIVAL of "full" 3-D computer graphics is indicated by talk of "3-D desktops and manipulatives". Individually tailored synthetic environments generated by modeling and computer graphics can be constructed relatively cheaply, and animating Feng-Shui advisories, for instance, constitute a potential software boom. Rendering such environments realistically remains a difficult compute-intensive problem, however, and other projects investigate the effectiveness of non-Euclidean interfaces, from gloves to virtual wind tunnels. Other research involves the development of industry-based navigable models of factory floors for training and evaluation, and the integration of these models into real-time, interactive, 3-D visualization systems that are accessible over networks. Finally, the application of GDP properties to the problem of 3-D geometric reconstruction could lead to the PRECISE specification via computer graphics of new but "historically authenticated" buildings and equipment, or to ARBITRARY yet structurally sound reconstructions of "imaginary" architecture.

Integration with IoT

Digital representation of real-world hardware, software, media, and devices in the virtual domain enables capabilities that are impossible or expensive in the real world. With the 3-D modeling capability presented, users can study the virtual assembly of a device where the real-world microscopic alignment of fibers or parts is crucial, and prevention, wear, maintenance, and acoustical and electrical properties can be simulated. It is also shown how a real-world mesh may be featured and endowed with linking to relevant information through 3-D annotations. The mesh loudspeaker prototype is used as an example, augmented [22]. In the past decade the Internet of Things (IoT) has grown to billions of devices in business enterprises, factories, homes, various industries, and whole cities. Yet, this growth seems to be hidden deeply in everyday computing. As the broader public adopts smart IoT devices in increasing numbers, the IoT as a whole needs new user experiences and small HCI technologies. Internet of Things is connecting billions of devices to each other, internet and even to humans. However, the visualization, command, and engagement with these systems are challenging tasks. New methods of interaction are needed to facilitate a user's control and sensible operation of their surroundings. When a person is thirsty, the real world system should understand the context and accordingly provide water.

ETHICAL CONSIDERATIONS IN 3-D TECHNOLOGY

Faster, improved microprocessor and software interfaces have provided intense 3-D viewing environments. Virtual Reality Modelling Language (VRML) has enabled the world to actually enter a 3-D computer generated environment. Applications for business, education and entertainment sectors are predicted. But as 3-D technology improves, it raises an increasing number of ethical challenges and concerns. Development is moving so rapidly that many ethical considerations are left behind. It may require more time to develop and refine the ethics of this new technology, as it is concerning to other technology professionals.

The goal of many of these technologies is to make virtual objects similar to physical objects. The results are that users will be unable to differentiate between the two, similar to in movies. There are three dimensional printers that are capable of actually making the physical objects in 3-D. This heightens the significance of the property rights of these objects. As with the spawning of the video camera-recorder boom of the late 80's, video and now 3DV cameras incorporated into AVFDs raise concerns [23].

Intellectual Property Issues

With these new technologies arise a number of new complications and problems. One of the major issues that have already come up is what types of works are copyrightable and/or for which a copyright license may be necessary. Everyone was not surprised when a Pulitzer-prize winning playwright and other writers objected to having their work used in one of these environments. Virtual reality seems like an entirely new ream of creative expression, but, in fact, so far these worlds look (and more importantly are rendered) in 2-D. This is where the patent attorneys come in. Of even great concern is what rights will come with these copyrighted works. What can the copyright holder's rights prevent others from doing? With these creative works come matters of tastes, morals, and aesthetics. How important are these non-discrimination concepts in a world based upon these types of environments? These concepts seem to require that a fine line be run, a line between protecting discriminatory copyrights and the concerns over anti-discrimination [24]. As with any technology, there will be a host of intellectual property ("IP") issues that will come with the territory. At its core, copyright law is creative expression, an activity that is potentially available to all. For this, arts and crafts will be treated as the same or substantially similar objects for determining statutory protection and infringement. All creative 3-D CAD files of original design will be protected by copyright law. 3D printing technology lowers costs by production externalities, may increase output and the number of creators. Both protection and enforcement options are considered for ensuring 3-D market efficiency [25]. The comparison of design of arts and crafts will be analyzed to see if infringement occurs based on similar or the same original design. Statistical tests are run to gauge the effectiveness of various enforcement mechanisms to ensure that investment in creativity continues.

Impact on Employment

Computers and geometric modeling are rapidly changing the way we interact with and design physical objects. Virtual reality technology allows designers, engineers, and scientists to "step inside" the 3-D models they create. Industrial and military researchers use this technology to simulate stress and airflow around an object and to determine its suite of virtual sensors prior to construction. Companies hope to use virtual prototyping to shorten development and production time. Store designers use virtual tours to sell their plans to customers and to run simulations of customer flow to optimize traffic flow. To further increase the effectiveness of virtual tours, there is also increasing interest in Head Mounted Displays. HMDs are akin to a motorcycle or fighter pilot helmet, and provide the viewer with a left and right high resolution screen positioned a few inches from the eyes. The use of HMDs removes the possibility of the viewer being distracted by their real environment and is a popular option for viewer-worn virtual environment.

Refinements in geometric processing by computers allow the smooth curves and surfaces made possible by advanced CAD software to be displayed more accurately and more cheaply. This allows greater communication between the designer and the virtual prototype. Additionally, 3-D objects pre-modeled can be incorporated for more informative aesthetics. Interfaces for 3-D apps do not model the real environment and the most common input device is a set of dials and numerical keypads. This hardware notoriously complicates some tasks and eliminates others. A solution to this is the Natural Modeling Interface. NATMINT allows the natural exploitation of the freedom of human hand by combining a hand-tied structure of pushbuttons and a computer 3-D space vision processing for real-time control of 3-D geometric models by hand-features and natural gestures.

RESULTS AND DISCUSSION

The integration of 3D technologies into computing systems has led to remarkable advancements across multiple domains, demonstrating both the potential and the challenges of this rapidly evolving field. This section presents the key findings from the research, highlighting the practical applications, technological progress, and emerging trends in 3D computing.

Technological Advancements in 3D Computing

The continued development of hardware and software has significantly improved the fidelity and performance of 3D environments. Virtual reality (VR) and augmented reality (AR) technologies have matured, with devices such as VR headsets and AR glasses providing more immersive and interactive experiences. Graphics processing units (GPUs) have become increasingly powerful, facilitating real-time rendering of complex 3D models, crucial for industries like gaming and simulation. Furthermore, the advent of 3D printers has revolutionized manufacturing and prototyping, enabling rapid production of physical models based on digital designs.

Applications Across Various Industries

The application of 3D computing is diverse, with notable contributions in fields such as gaming, healthcare, architecture, and education. In gaming, 3D environments have enhanced user immersion, making virtual worlds more interactive and realistic. The healthcare sector has benefited from 3D modeling and printing, which allows for precise anatomical models used in surgical planning and education. In architecture, 3D design tools have streamlined the creation of intricate building models and facilitated virtual walkthroughs, which can aid in decision-making processes before construction begins.

Moreover, 3D computing is playing an essential role in industries like automotive design and aerospace engineering, where simulations in 3D space are used to test prototypes and streamline production. The entertainment industry has also seen significant growth, with filmmakers and animators using 3D tools to create visually stunning films, animations, and special effects.

Challenges and Limitations

Despite the rapid growth of 3D computing technologies, several challenges remain. One of the primary obstacles is the cost of high-end 3D hardware, which may limit access to these technologies for smaller businesses or educational institutions. Additionally, the complexity of creating detailed 3D models often requires specialized expertise, raising barriers for those who wish to adopt 3D computing without a steep learning curve.

Another limitation is the need for more efficient software and algorithms capable of processing large 3D datasets quickly and accurately. As 3D environments become more detailed, rendering times can become prohibitively long, especially in industries requiring real-time processing, such as gaming and simulation. Similarly, the resolution of 3D models and environments still faces limitations in terms of realism and detail, which continues to be an area of ongoing research and development.

Ethical and Social Implications

The growing presence of 3D technologies raises several ethical concerns, particularly regarding privacy, data security, and the potential for misuse. The ability to create hyper-realistic digital models of individuals or environments could lead to issues surrounding identity theft, deepfakes, and virtual surveillance. Additionally, the immersive nature of VR and AR could have psychological effects, including addiction, disorientation, and detachment from the real world.

There are also considerations regarding the environmental impact of 3D printing, especially in industries where materials used in the process may not be environmentally sustainable. Efforts to reduce the carbon footprint of these technologies are still in early stages but must be prioritized to prevent further environmental degradation.

Future Directions

Looking ahead, the future of 3D computing holds immense promise. With the rise of the metaverse and continued advancements in AI and machine learning, 3D systems will likely become even more sophisticated and integrated into daily life. For instance, AI-powered algorithms are expected to improve the efficiency and accuracy of 3D modeling, enabling automatic generation of complex designs based on minimal user input.

Moreover, the intersection of 3D computing with other emerging technologies, such as 5G, could enable faster and more seamless experiences in VR and AR, further blurring the lines between the physical and digital worlds. The growing use of haptic feedback and sensory technologies will also contribute to making 3D environments more immersive and tangible.

In conclusion, while 3D computing technologies have already transformed numerous sectors, their full potential is far from realized. The continued evolution of these technologies will drive innovation and open up new opportunities across industries. However, it will be essential to address the challenges and ethical implications to ensure the responsible and equitable development of 3D computing systems.

CONCLUSION

While there is still progress to be made in 3D image processing, its place is already certainly in the very rich toolbox of research fields dealing with the project. This study is devoted to presenting some fields in which the project has shown interesting applications. This study is organized in two distinct parts, depending on whether the project is used to acquire 3D data or to display it. In many cases, the same project can be used in both parts. It is the case of the fields of quality assessment, processing or watermarking of 3D data. In some cases, there are direct parallels between 2D and 3D image processing. For example, 3D image denoising can often be obtained as a simple generalization to three dimensions of a 2D denoising algorithm. However, in general, 3D image analysis tends to be more challenging. Beyond the acquisition of data, search, and navigation, the 3D processing task deals typically with point set shaping. This study explores various uses of 3D projects, focusing on analyzing captured scenes and retrieving 3D objects. In particular, 3D scene analysis from acquisition to larger defect segmentation and 3D object retrieval from extremely complex large databases are discussed [26]. The obtained scan point cloud has the aspect of set of isolated points, although multiple points originate from the same surface. Additionally, neighborhood connections are not included in the data and must be discovered by data analysis. As for other point processes, kissed properties are reflection of the proximity of neighboring point. A search can be undertaken to find neighbors in the point cloud, an appropriate data structure must be used for processing of the data. The most popular efficient structures are KDD trees, but there also octrees or space filling curves. The distance is typically computed in a greedy way, by visiting all points. However, sophisticated data structure exists for approximate fast k-nearest neighbors' search. The gathered point cloud is not an isolated set, but connected with the rest of the sampled scene. Taking this global topology of the data into account can boost the quality of the estimates significantly. There are several ways to derive pertinent representations of the global scene for that purpose, but it is also desirable to largely reduce the complexity of the data set. The problem of surface extract from a 3D point cloud is discussed. After reviewing the existing topology estimation technique applicable to the problem, a tailor surface extraction technique is described that integrates the neighborhood information in the point cloud. It involves accurate normal estimation, followed by mane transport. Finally, results are provided on several 3D scanned data sets, demonstrating the effectiveness of the developed analysis.

In 2025, advancements in 3D computer vision, AI, and hardware are expected to lead to more accurate algorithms, real-time scene understanding, and integration with technologies like IoT and 5G, impacting industries like autonomous vehicles, healthcare, and robotics.

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