Virtual Reality

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Viareggio, 18 January 1997

Introduction

Over the last four years I have talked to you about several topics: artificial intelligence, the theory of chaos, the Internet, and finally last year, on multimedia. I have been becoming lazier every year, using each year as an opportunity to "steal" material from the previous year.

This year will be the laziest year of all. I chose the topic of "Virtual Reality" for my lecture because it allows me to steal material from *every single previous lecture* I have made here at the Anglo-Italian Club of Viareggio. If I try hard, I won't have to tell you anything new at all, just mix up pieces of my old lectures!

Of course, I'm only joking to a certain extent—but behind all of this joking is a serious message. In my lecture on the Internet two years ago, I made an observation about the convergence of information technologies:

> "As the twentieth century nears its end, the lines are blurring between different kinds of information. The television, telephone, and computer industries are all converging together, and merging onto the information superhighway. Soon they will be traveling together on the same pathways and will become indistinguishable from each other."

Last year in my lecture on multimedia, we saw the results of this. We saw how multimedia connects together the written word, sounds, and images. We saw how encyclopedias are brought to life in an electronic way that isn't linear any more, but an abstract representation. In the real world you turn the pages of an encyclopedia and look up cross-referenced information. But in the world of multimedia, words sounds, and images are connected to each other in an abstract way through hyperlinks that allow you to navigate in ways that don't exist in the real world. In other words, multimedia is used to create a different kind of world than the real world: a *virtual world*, that exists only in your mind, with no immediate correspondence to real objects.

This is the ultimate goal of the convergence of information technologies that I was talking about earlier. All of it has been leading up to man's most ambitious goal to achieve with the use of computers: the creation of virtual reality.

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The Basic Visual Technology of Virtual Reality

Virtual reality can be thought of in a general way as “multimedia with all of the senses.” While this isn’t really a very precise description, it’s not a bad start. Now, certainly the most important of the senses is our vision. Without convincing visual perception, virtual reality wouldn’t get very far. So I’ll start by reviewing with you the most important advances in realistic computer graphics that have begun to make virtual reality a possibility.

Fractals for generating landscapes

You will remember from my lecture on Chaos that fractals are the mathematics of nature. Fractals have made it possible to model natural scenes with the computer in a very realistic fashion. They are used especially in scenes of simulation, for modeling the landscape. But not only is it now possible to model terrain, but also trees and plants.

Morphing

Image processing has made great advances in recent years. New techniques for the transformation of images have made it possible to create an amazing variety of visual effects with the computer. One of the most spectacular effects that have become popular in recent years, especially in the “special effects” movie industry, is called “morphing.” This is the gradual transformation of one image into another by a special program.

Simulation

Fractals and morphing are very impressive technologies, but they are essentially only techniques for the creation and manipulation of images, in two dimensions. (This is not strictly true for fractals, but nearly so.) Now we show how these basic technologies can be used for the next step, which is real modeling in three dimensions. In this way, things can be created that can be viewed with perspective.

The most important combination of fractal landscapes and three-dimensional modelling is in simulation. The military were among the first to work in simulation.

Ray Tracing

Ray tracing is the basis for the most realistic pictures ever produced by computers. In ray tracing, a real model is built inside the computer, which makes it possible to calculate things like shadows and lighting, and movement. Every single ray of light is traced from the model to your eye. It is the basis for the most advanced virtual reality. You can imagine how computation intensive it is.

Full Computer Animation

All of the above techniques are finally combined to the ultimate virtual reality experience, of which the latest and greatest example is *Toy Story*. One example shown in my talk is a completely modeled figure of a woman in a bathing suit walking. Another example shows a very realistically modeled Raptor dinosaur, straight out of *Jurassic Park*. It is difficult to imagine a more realistic picture of something that does not even exist. Finally, Gabriele Salvatores (of *Mediterraneo* fame) has just made a picture, called *Nirvana*, which deals with virtual reality.

Immersive Virtual Reality Applications

All of the basic techniques above produce amazingly realistic three-dimensional scenes. But they are only the visual building blocks of virtual reality. Two more very important aspects must be added:

- the other senses (such as hearing and touch) must be treated;
- it must become interactive. The scenes discussed above were passive.

Now, fully interactive virtual reality applications where the senses such as touch and hearing are involved are the most complicated and expensive in existence. These are called *immersive* virtual reality applications, because you are “immersed” in a virtual environment with all of your senses. (In fact, not all of the senses have been treated very completely yet—although there are now some preliminary experiments in the use of the sense of smell.)

Usually an immersive virtual reality application involves wearing some kind of special helmet or eyeglasses for the eyes, and special gloves for the hands.

I’m afraid it would be impossible for me to demonstrate any full immersive virtual reality applications here, because of all the equipment that would be necessary. But I’d like to describe a couple of representative examples.

The Virtual Workbench—Virtual Medicine

This is a more serious application, which should convince you that virtual reality is becoming important for practical applications. One of the most promising applications is virtual medicine—the use of virtual reality to help doctors perform various tasks in a virtual environment rather than a real environment involving the human body. This can range from “virtual operations” in which a surgeon operates on a computer representation of the body; to immersive images of a human organ (such as the human eye) in which a doctor can navigate inside the structure of that organ in order to study it (remember the movie *The Fantastic Voyage*, which involved an imaginary voyage inside the human body?); to “teleoperations” in which a surgeon in one place, such as Tokyo, carries out an operation on a patient located in another place, such as Milan.

The virtual workbench is a virtual reality environment designed especially for delicate handwork. It includes the use of special glasses, and special gloves that the operator wears. The virtual workbench is also being used for eye surgery.

Researchers at the Medical College of Georgia and IMTC at Georgia Tech have created a device incorporating virtual reality to simulate the look and feel of eye surgery. A primary benefit of the simulator is to provide an environment for time-critical training for medical students and practicing surgeons. By using this system, surgeons can practice coping with emergencies and the unpredictable, as do pilots with flight simulators. Beside photo-realistic images of the eye, the simulator has tactile feedback for real-time "feel" of tool-tissue interaction.

Here is their description of how it works: the operating station for the simulator has the viewer interacting with a 3D virtual eye using a virtual surgical instrument controlled by a handheld 6D tracking stylus that continuously reports position and orientation to the computer. The tip of the stylus is connected by thin rigid bars to

three motors that generate *force feedback* in response to the instrument's interaction with virtual tissue. (See the glossary for definitions of *force feedback* and *tactile feedback*.) As the knife makes contact, the white of the eye (*sclera*) slightly deforms until the blade penetrates and starts to cut. The force feedback system produces a compliant or "springy" resistance as the sclera deforms and then allows the blade to slice through the sclera with a small viscous resistance in the cutting direction after penetration. As the blade is cutting, a strong compliant force is generated in the direction perpendicular to the cutting axis to produce the same type of resistance that would be experienced if the surgeon tried to move the blade in the wrong or non-cutting direction. Through the technology the procedure can be recorded, quantified and replayed for evaluation by the student and instructor.

Here are some of the benefits they list from this kind of virtual reality technology:

- No risk to patients by surgeons in training
- Reduced use of cadavers and animals
- Surgical complications and maladies that are rare can be presented to students as part of routine training
- Established surgeons can learn new techniques
- An especially difficult surgery can be "rehearsed" before operating on the patient
- Can view procedure from several different perspectives - even from inside the eye - seeing if cuts were made at the correct depth and proper angle
- Renew a surgeon's certification and establish surgical privileges in hospitals
- Surgical technique can be recorded and replayed for evaluation
- As Telemedicine advances, a surgeon's expertise can be remotely brought to those in need not living near a major health care provider.

The CAVE

One of the most prominent initiatives in immersive virtual reality is a project called the CAVE at the University of Illinois. One meaning of the acronym is "Cave Automatic Virtual Environment." (Another is mentioned below and expanded in the next section.)

The creators of the CAVE are two professors: one is a professor of art, and the other is a professor of computer science. They have been collaborating since the 1970s, and some of their results provided the basis for the landmark special effects of the *Star Wars* movies. They call the CAVE the "first revolution in perspective since the Renaissance."

Here is what the creators of the CAVE say about it:

> Virtual reality may best be defined as the wide-field presentation of computer-generated, multi-sensory information which tracks a user in real time. In addition to the more well-known modes of virtual reality—head-mounted displays and binocular omni-oriented monitor (BOOM) displays—the Electronic Visualization Laboratory at the University of Illinois at Chicago introduced a third mode in 1992: a room constructed of large screens on which the graphics are projected onto two to three walls and/or the floor.
>
> The CAVE is a multi-person, room-sized, high-resolution, 3D video and audio environment. In the current configuration, graphics are rear projected in stereo onto two walls and the floor, and viewed with stereo glasses. As a viewer wearing a location sensor moves within its display boundaries, the correct perspective and stereo projections of the environment are updated, and the image moves with and surrounds the viewer. The other viewers in the CAVE are like passengers in a bus, along for the ride!

> **CAVE,** the name selected for the virtual reality theater, refers to "The Simile of the Cave" found in Plato's *Republic*, in which the philosopher explores the ideas of perception, reality, and illusion. Plato used the analogy of a person facing the back of a cave alive with shadows that are his/her only basis for ideas of what real objects are.

The Philosophical Implications of Virtual Reality

In this section I'd like to make a digression into philosophy. The creators of CAVE described Plato's *Republic* as the inspiration for the name they gave to it.

In ancient times, philosophers were also scientists. Many of their writings were not only about metaphysical questions (like "is there a God?") or ethical questions (like "What are good and evil?"), but questions about the nature of the world (like "what are the basic building blocks of matter?").

Up until only a few centuries ago, scientists were also philosophers, in the sense that there was always a strong connection between the study of nature and the study of the philosophical implications of their results. One of the most famous examples of this took place right here in Pisa, where Galileo was forced to renounce his theory that the earth rotated around the sun because of the theological implications (theology and philosophy used to be linked even more closely than they are now).

But gradually the scientists and the philosophers began to drift apart in recent centuries, and in fact we began to see scientists with very little or no training in philosophy. They only did their work studying nature, and didn't care very much about whether there were any philosophical implications.

But physics in the twentieth century has begun to change all that. Many of the scientific discoveries of the twentieth centuries have so completely altered our previous view of the world that the body of philosophy we have is no longer adequate. In particular, our view of the world after the discovery of quantum physics and relativity theory is no longer intuitive. We can't imagine the world implied by these results from our experience. (I have never traveled close to the speed of light. Have you?) Bertrand Russel, the famous English philosopher, in his *History of Western Philosophy*, wrote that

> The philosophy appropriate to quantum theory ... has not yet been adequately developed. I suspect that it will demand even more radical departures from the traditional doctrine of space and time than those demanded by the theory of relativity.

Virtual reality is another technology that will force us to think again about our traditional reservoir of philosophy. One of the oldest questions in philosophy regards the nature of reality itself: *what is perception*?

Plato was the first to write about the concept of duality of all objects between the form of the object, which is perfect, and its imperfect realizations in the real world. Although his intent was not the same, of course, it is hard to avoid thinking about an analogy between virtual reality and concrete reality. Plato was therefore the first to treat the (still unsolved!) philosophical problem of *universals*. (For example, he said that there was just one perfect "table" and many imperfect realizations of "table" in the real world.)

The seventh book of the Republic contains the dialogue of the *simile of the cave*, and it is uncanny how it reminds us of virtual reality:

> "And now, I said, let me show in a figure how far our nature is enlightened or unenlightened: Behold! Human beings living in an underground cave, which has a mouth open toward the light and reaching all along the cave; there they have been from their childhood, and have their legs and necks chained so that they cannot move, and can only see before them, being prevented by the chains from turning round their heads. Above and behind them a fire is blazing at a distance, and between the fire and the prisoners there is a raised way; and you will see, if you look, a low wall built along the way, like the screen which marionette players have in front of them, over which they show the puppets."
>
> "I see."
>
> "And do you see, I said, men passing along the way carrying all sorts of vessels, and statues and figures of animals made of wood and stone and various materials, which appear over the wall? Some of them are talking, others silent."
>
> "You have shown me a strange image, and they are strange prisoners."
>
> "Like ourselves, I replied; and they see only their own shadows, or the shadows of one another, which the fire throws on the opposite wall of the cave."
>
> "Surely."
>
> "If those prisoners could converse among themselves, do you not agree that they would think real objects to be their visions?"
>
> "Necessarily."
>
> "And if the prison had an echo from the front wall? Every time that the voice of somebody passing by were heard, do you think that they would judge it any differently from the voices from the passing shadows?"
>
> "Why no, of course not!"
>
> "For such persons therefore, I said, reality can be nothing more than the shadows of artificial objects."

And this is something written 2400 years ago!

Right now, with the purely visual objects of computer graphics, it's not hard to say that they don't really exist. But when you start adding the other senses, like touch and hearing, and then interaction, feeling the weight of objects, their resistance, affecting their behavior—the border between virtual and real, between perception and reality, becomes less and less clear. More and more, virtual reality technology makes us contemplate the possibility that even our physical senses are just information processors, delivering information to our brain.

Now let us consider the consequences of that. Let me take up Plato's idea of prisoners in the cave who had been there since childhood—that is, *for their entire lives*. What would it be like to grow up in a world of only virtual reality? (By the way, there was an amusing movie several years ago called *Being There*, starring Peter Sellers, about a man who had grown up and spent his entire life watching television, and so the only world he knew was the world of television. In the movie, he was nearly elected President of the United States!).

In my artificial intelligence lecture, I talked about the *brain in the bottle* problem: one of the biggest philosophical objections to the possibility of artificial intelligence was the theory of a professor at the University of California at Berkeley, Hubert Dreyfus, that you had to have a *body* to acquire intelligence. It was the vehicle for sensory experience in the real world. Up until now, only humans had bodies. But if virtual reality provides sensory information, maybe you don't need a body, just the "inputs" from virtual reality. Would it be possible to distinguish the difference?

Now, I don't want to overdo it here. It would require much more competent professional philosophers to have a really serious treatment of the philosophical aspects of virtual reality. But it is fascinating that virtual reality has brought us back full circle to the ancient Greeks.

(Those interested in this subject might also want to explore the philosophy of Kant, who postulated that our mental apparatus gave structure to external objects. Thus they did not exist in space and time one their own, but only appear that way because *we* give them that interpretation. Again, an uncanny echo of virtual reality can be heard here.)

Virtual Reality in Cyberspace

After that philosophical digression, it's time to get back to our discussion of virtual reality technology today. I want to get away from the fancy, flashy immersive virtual reality technology, and talk about another kind of virtual reality that isn't as impressive technically, but every bit as important as these big immersive, multi-sensory applications. In fact, perhaps it is even more important.

I am talking about bringing virtual reality to cyberspace.

Now, it may not be entirely clear to you what I'm talking about. To understand what we mean, remember that the virtual reality I showed during the multimedia lecture was all on CD-ROM. You can buy virtual walkthroughs of museums, etc. But they are on CD-ROM. You can't "send them" through the Internet.

In a way, what I'm talking about is similar to the difference between records and radio, and videotapes and television. Records and videotapes are physical objects. You can play them yourself, but you can't send them anywhere. But radio and television make it possible to distribute them everywhere.

Now, the individual technology of a CD player is more impressive than the technology of a radio. But the power of radio to bring music to the masses far outweighs its technical disadvantages over a CD player. Likewise, you can sit in a cinema and watch a movie on a huge impressive screen, with surround-sound speakers. But even though the same movie is technologically less impressive on the small television screen, the social implications of this mass distribution are far greater.

And so it is with Virtual Reality in the laboratory versus Virtual Reality in Cyberspace. In its beginnings, the Internet was just a medium for textual communication, like electronic mail. We saw some examples of this in my Internet lecture. Then, during my multimedia lecture, we saw how the World Wide Web made it possible also to distribute graphics. Now there are efforts to bring virtual reality technology to the Internet, so that it can also be distributed.. Of course, the technology is not as impressive as we have seen in the CAVE or the Virtual Workbench, but that will improve with time. And the implications are enormous

VRML — The Virtual Reality Modeling Language

The most well known initiative today for Virtual Reality in Cyberspace is something called the Virtual Reality Modeling Language, or VRML. The experts call it

"vermel." This is a big, well-financed initiative, and companies like Microsoft and IBM are supporting it very intensely.

The VRML makes it possible to send interactive three-dimensional graphics through the Internet (or more precisely, through the World Wide Web). It allows you to model three-dimensional scenes using some relatively primitive mechanisms, and gives you some basic possibilities for interaction with the user. Now, it may be difficult to think of the primitive scenes that you see as virtual reality, but many of the same benefits are still obtained, such as the ability of the user to navigate through a complicated three-dimensional world and have some kind of interactive experience.

VRML Browsers

Now we will discuss *how* virtual reality is brought to the World Wide Web. There are now programs that enhance the Web Browser to handle not only the kinds of things I showed you before on the World Wide Web, but also VRML.

I have one here today, which is a so-called Netscape Plug-in called "WIRL."

This makes entirely new applications possible. It is now possible to have three-dimensional animations on Web Sites. Do your remember the Anglo-Italian Club Web Site I demonstrated in the Multimedia lecture? It was "flat". There was no animation. It was two dimensional. There were the so-called "hyperlinks" from one page to another, but this was just navigation, not real interaction and certainly not three-dimensional.

For example, a Web Site might want to show a three-dimensional animated graph of its data. **The Netscape Stock performance demo** in WIRL shows an example of this.

Internet Commerce

One of the most important is Internet Commerce. A store advertising on the World Wide Web can now have you "walk through" the store and look at the things you might buy, for example.

A good example of this is how a Web site selling furniture by mail order might also make three-dimensional interactive instructions available. The **Television Cart Assembly demo** in WIRL demonstrates this.

JAVA

Although the VRML is precisely created for virtual reality, the most important new Internet language, called JAVA, can also be used for sending virtual reality through the Internet. The WIRL Netscape Plug-In has a JAVA demonstration.

Conclusion—Virtual Reality and the Power of the Mind

If you want to read more about Virtual Reality, here is a reference to a book which was published here in Italian translation. I'm afraid I haven't seen it myself yet, but the author is very well known in "cyberspace" circles, and I am sure that the book is very provocative.

> Howard Rheingold, "*Realtà virtuale. I mondi generati dal computer e il loro potere di trasformare la società*, Baskerville, Bologna 1993.

The author, Howard Rheingold, is the person who invented the name “virtual community.” He is the high priest of the idea that the Internet is turning the entire world into one single virtual community, a “global collective consciousness.” (In fact, if you have access to the World Wide Web, you might want to visit his web site at *www.minds.com*.)

Let us consider the idea of the virtual community a bit further in the context of virtual reality. It is ironic that, for all of the powerful Virtual Reality technology we are seeing today, the most powerful component of any VR experience remains the human mind itself.

On the Internet today there exist games called MUDs— Multuser adventure games. They are played by people through the Internet who sit at their computers and play roles, invent new universes, etc., all through the simple dialogue of the keyboards of their computers. This might be called “narrative virtual reality”, which uses nothing but the imaginative power of the human mind to create a virtual reality experience. A friend of mine actually met his wife through one of these games, and recently he described his experience to me in a letter:

> My relationship with VR is somewhat a-typical - having encountered and courted my wife in there. Many VR fans and practitioners refuse to categorize multi-user internet adventure games (MUDs) as VRs, since they generally don't rely visual or other direct sensory input - instead using narrative text to create an image of a universe in your mind. Those who have tried it - and who have a bit of imagination - quickly realize that it is an immensely powerful medium, however. In fact, given the current level of "real" VR technology, it's like comparing a good book with the pioneering efforts at motion pictures. Which medium is more powerful - the book or the perforated cardboard disc spinning in front of a candle? If you have a good imagination (fueled by lots of science fiction literature and too much cramming for school), a MUD can hit you like a hammer between the eyes, and you literally risk dropping out of the world for a period of half a year or more. I first came across MUDs right after cramming for a math exam in college, and I was ready for the diversion. I was lucky, I suppose, since it was only a month or so before I got caught up in the technical aspects and started programming again. It still stands in my mind as one of the most bizarre periods of my life. Still, I was lucky - between the concrete experience I gained, my meeting my wife, and having my absolutely wonderful son, I came out of it a much richer person.
>
> You basically discover that inside of this little green terminal is an entire universe - where the laws of nature and all of its physical limitations are either different or suspended entirely. The universe is populated with fantastic beings and people who - because of the bizarre effect that online communication has on you - often seem more *real* than the person sitting at the terminal next to you. To say that it is addictive is a massive understatement. Fortunately the effect wears off - I haven't been near those games for 5 years or more.
>
> I am still not convinced that "real" VR will ever become convincing and seamless enough to be as powerful as narrative VR. Your language center is a very powerful part of your brain, and it is every bit as well connected as your visual center.

Glossary of Virtual Reality Terms

The following are some current definitions of virtual reality terminology gleaned from the Web, as proposed by typical companies selling virtual reality services.

3D Sound: Sound produced so that it seems to come from various spatial locations. It is typically produced with only two speakers, such as those in headphones.

Body Suit: Full-body-covering clothing interfaced to a computer system to allow the wearer to interact with cyberspace.

Cyberdeck: The machinery that creates and maintains cyberspace.

Cybernetics: The study of communication and control processes. Often used to indicate a conceptual connection to or control by computers.

Cyberspace: A virtual space, occupied by one or more human beings, created and maintained by computers and other machinery.

DataGlove: Trademark of VPL Research Inc. for their input glove.

EyePhone: Trademark of VPL Research Inc. for their stereo-optic, head mounted display system.

Force Feedback (FFB): The simulation of weight or resistance in a virtual world. (Compare to Tactile Feedback.) Force feedback requires a device which produces a force on the body equivalent (or scaled) to that of a real object. It allows a person in cyberspace to feel the weight of virtual objects, or the resistance to motion that they create.

Glove, Input: The glove used to measure the flexure of the hand and relative positions of the fingers and input that data to the computer mediating a virtual world. Brand names include DataGlove (VPL Research), CyberGlove (Virtex Virtual Technology), Dexterous HandMaster (EXOS), PowerGlove (Mattel Toys) and others.

Head Mounted Display (HMD): A device, which is fastened to the head, and used to display a computer-generated scene. A Head Mounted Display typically provides a stereo-optic (3D) view through the use of two LCD or small CRT displays. Brand names include EyePhone (VPL Research), Visette (W-Industries), Private Eye (Reflection Technologies) and others.

Interpupilary distance (IPD): The distance between the pupils of the eyes.

Joystick, 3D: A joystick is a control device, often attached to a fixed base, for controlling computers or machines by moving in 2 dimensions (forward/back, right/left) on its base. A 3D joystick adds control in the third dimension (up/down) and may be free or fixed.

Pod: Capsule or cabin designed to hold one or more players in a VR-based game. Typically a pod includes connections for I/O devices such as HMDs, headphones, joysticks, etc.

Teledildonics: Remote sexual experience. Hypothetical.

Tactile Feedback (TFB): Sensation applied to the skin, typically in response to contact or other actions in a virtual world. (Compare to Force Feedback.) Tactile Feedback can be used to produce a symbol, like Braille, or simply a sensation that indicates some condition.

Telepresence: The ability to act and interact in a distant environment through cybernetic technology. The electronic analog to an out-of-body experience.

Trackers, Position: Devices that report the location of objects in the real world to computers controlling virtual worlds. Typically, position trackers are attached to head mounted displays (see above) and to input gloves. Position trackers work via various technologies, including direct connection, magnetic sensing, acoustic or optical tracking. Manufacturers include Ascension Technology, Logitech, Polhemus, Shooting Star Technology, and others.

Virtual Reality (VR), Virtual Environment (VE), Artificial Reality (AR), Synthetic Environment (SE): That sense of place and being which exists in cyberspace. Artificial Reality implies non-immersion technology, such as Myron Kreuger's Video Place. Virtual Reality commonly implies full-immersion technologies using goggles and similar devices. Virtual Environment and Synthetic Environment are terms typically used by the US Defense Department and Space Agency and carrying the same essential meaning. The three-part test for Virtual Reality:

1. Computer-mediated experience.
2. Objects in the virtual world are modeled using 3D techniques.
3. System gives random interactivity.

Virtual: Existing in essence or effect, but not in actual fact.

VRML: *Virtual Reality Modeling Language*, a language for sending three-dimensional interactive graphics through the Internet (simplified definition).