SYNTHETIC PHYSICS: IDEAS FOR NEW WORLDS

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While the physical laws of our real universe cannot be modified, in virtual computer-generated worlds arbitrary physical laws can be implemented. However, critical constraints of synthesizing such physical laws are given by our sensorimotor system and by the consistency of the resulting virtual world. It is proposed that synthetic physics has an enormous potential not only for education but also for creating art using physical laws as medium.

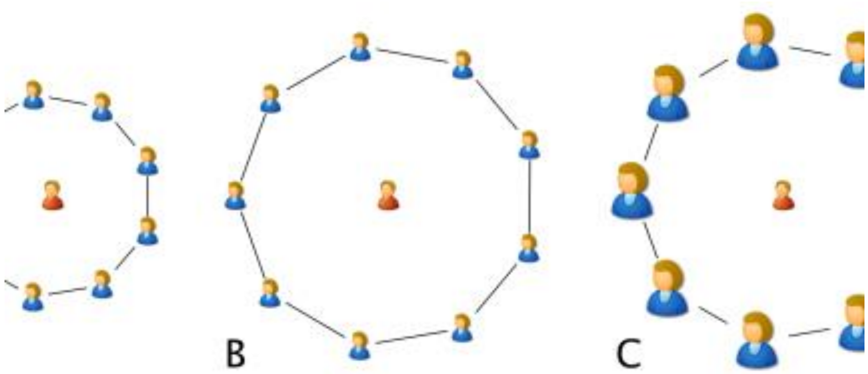

Figure 1: Example for the violation of consistency. A: initial situation: persons at a constant distance form a circle around the viewer. B: each person steps back so that their interpersonal distance increases and they can no longer touch each other. C: for the viewer in the center, the visual angle increases due to the Turtur-effect (see text), which means that the apparent distance between the persons seems to decrease: touching each other seems possible, while physically it is not.

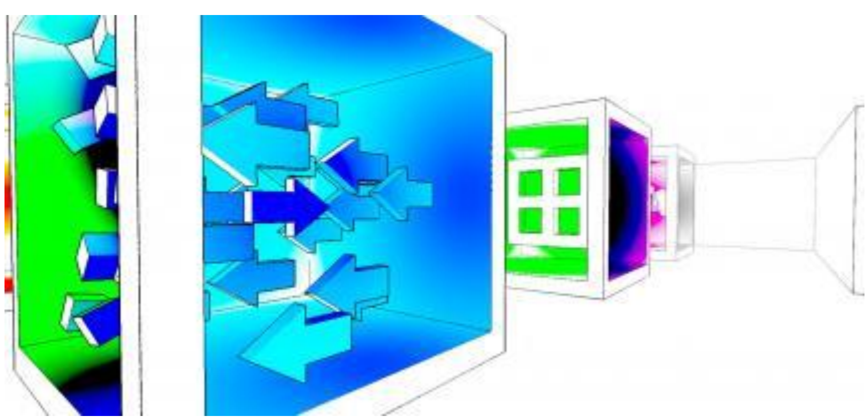

Figure 2: The computer game Antichamber [11], which claims to abandon Euclidean geometry (screenshot courtesy Alexander Bruce).

Introduction

When we enter one of the many virtual worlds available nowadays, be it a simple flat world represented in a browser game or a sophisticated three-dimensional world in a high-end computer game, we usually expect that most of the basic rules of every-day physics and geometry in the real world are implemented also in the virtual counterpart. The geometry is Euclidean, objects look smaller when farther away, there's an up and down, and if things fall, they fall down. Sometimes we can fly in a virtual world, sometimes things do not cast shadows, but in principle all the rules are a simplification of the real-world physical laws. But is that really necessary? Can't we go "beyond physics"? [1]

In the following, these rules or laws will for simplicity be called 'synthetic physics' – denoting not only the basic underlying rules of how objects and agents should physically interact with each other and the simulations performed by the so-called physics engine in game engineering, but also more generally all rules concerned with physics such as the topology of the simulated space or the laws of synthetic optics. So far, the designers of multi-user virtual worlds seem to have adopted the simplistic approach of taking the physical laws of reality, simplify, and use the result as blueprint for synthetic physics. But already in the mid-90s Michael Benedikt suggested that the space of possibilities allows for more. [2] After providing examples of 'impossible' physics - most of which are actually dealing with spatial topology rather than physics in the real-world sense - he proposed several principles meant to serve as guidelines for the successful design of cyberspace.

Real physics

Before discussing these design principles, we need to take a closer look on the real physical laws and the simplifications made by metaverse designers. Take any physics textbook, and you will immediately realize that not all physical laws are relevant for our experience of the world. Special relativity does not have any impact on our daily life, and we need not be aware of quantum physics to catch a ball. In fact, we do not even need to know about Newtonian physics; mankind did well without explicitly knowing about it for most of its history. However, when trying to design a considerably convincing replica of the real world, it becomes important to consider which physical laws should be implemented. To date, the sensorimotor constraints in interacting with a virtual world are provided by the interface technology. The main sensory input supplied by multi-user virtual worlds is vision and audition, the latter often playing a subordinate role. Consequently, the main effort in implementing real-world physics goes into providing a decent graphics engine, realistic sound sources, and rigid body dynamics. Other aspects of real-life physics such as fluid dynamics are usually omitted. Evidently, some omissions affect the amount of realism, whereas others do not, such as restricting the simulation of electromagnetic radiation to the visible spectrum rather than implementing, e.g., radio wavelengths. The simplifications lead to unreal – or hyper-real – [3] physical environments, which can provide an unexpected educational potential: virtual physics invite to experiment with physical laws rather than just simulating real physics. [3]

Psychophysics

Nonetheless, with the user being the central element of any virtual world, the implementation of physical rules needs to be adapted to the capabilities of the users. Here it is where psychophysics come into play: neuroscience, rapidly advancing during the past decades, and experimental psychology, building on the psychophysical foundations laid out in the past century, tells us how perception works, how experiences are generated, how we react to changes in the world, and how we interact with the world and its objects. One of the most important insights is that we do not directly sense the physical properties of objects, but estimate them based on multisensory input and prior experience, which may be innate or acquired over time by learning. Our perception is thus an indirect estimation process rather than an accurate measurement of object properties. Besides relying on sensory information, the perceptual estimation processes are based on general assumptions about the world. Perhaps the most important one is the assumption of constancy (color constancy, size constancy, etc.). These constancy constraints or invariances, reflecting the statistics of the environment in which we live, are assumed by many researchers to be the basis for our perception. Our actions are shaped by knowledge about the statistical properties of the world and thus we implicitly assume that the statistics of the world do not change rapidly. We thus may formulate, following Benedikt, [2] a 'Principle of Constancy' for the design of virtual physics to meet the abilities of our human perceptual and motor systems.

But which of the properties of the real world need to be preserved in a virtual world for humans to be able to interact with it? In our opinion, some of the a-priori assumptions of everyday sensorimotor processing, such as the existence of gravity, need not to be implemented and can be ignored without significantly affecting action and perception within virtual environments. But we seem to be able to deal with much more drastic alterations: a recent study claims convincingly that humans, given extensive training, are able to efficiently navigate a four-dimensional maze-world. [4] Thus, we apparently can adapt to properties of a virtual environment that most of us consider as being completely unimaginable. Another study investigated how humans behave in physically impossible environments and whether they consciously notice the violations of Euclidean metrics or planar topology. [5] The surprising and conceptually far-reaching finding is: you do not realize it. And you behave just like in a normal virtual environment that mirrors the metrical and topological properties of the real world. Thus, in contrast to Kantian ideas, a-priori properties of space such as Euclidean geometry do not seem to be required for spatial behavior.

Alternative physics

Can we thus conceive of alternative physics, which, nonetheless, allow for interaction with content, be it user-created or supplied by the virtual world, and with other users? We think that it is possible to create virtual worlds with such alternative physics without completely disorienting the users. It could even be possible to have different physics within a single virtual world, allowing the user to change certain physical parameters, properties, or even rules within a given, carefully selected set of meta-rules. This set of meta-rules needs yet to be defined, and an interdisciplinary approach of physics, mathematics, and cognitive science will be required to do so. Creativity paired with analytical capabilities and profound knowledge is asked for to design such a rule set with its most important ingredient being consistency.

Let us take an example from fiction to illustrate what consistency means. Michael Ende describes in his novel for children "Jim Button and Luke the Engine Driver" a character called Mr. Turtur. [6] Mr. Turtur is a pseudo-giant: he appears to be a giant when viewed from far away, but when you approach him, he seems to shrink and finally is just as tall as any other human being. This character works well within the novel, but would not be consistent as alternative physical possibility, since, for example, a normal person standing next to him and holding his hand would become inconsistent: either the arm of Mr. Turtur or that of the person holding it would need to be distorted to not appear to loose contact. One possible solution seems to be that everything should grow in apparent size with increasing distance. But this solution would again violate consistency: imagine looking at a circle of people holding each other's hand around you. The circle is quite close to you (Figure 1A). If each person steps back a certain distance, they loose each other's hands, because the circle grows (Figure 1B) and the interpersonal distance increases. But for you it would *look* as if they could still hold their hands, since their apparent size grows (Figure 1C). Your view and the physical facts are thus no longer consistent, not to speak of how persons in the circle would appear to each other.

Note, however, that the notion of consistency does not contradict the finding that Euclidean geometry is not important to solve spatial tasks. [5] Even though it may seem as if a triangle with three 90° angles is inconsistent, it is, in fact, not inconsistent in itself but just with Euclidean geometry. Thus, in a different geometry, which is not physically possible in our world, the triangle can have three right angles.

The potentially beneficial use of breaking specific real-world assumptions for the design of interaction techniques has been investigated by Pierce & Pausch. [7] In their example, landmarks such as towers used to navigate over intermediate distances do not completely vanish with distance but remain at a minimum size. While this proposal, which clearly reminds of Mr. Turtur, breaks the continuity of space (the landmarks 'grow' relative to their surrounds), it can help users to navigate in an environment by serving as virtual beacon.

As Benedikt [2] points out, art and fiction have described many possible alternative worlds and the boundaries for the fantastic seem to be stretched as far as possible. We need not even go as far as theoretical physics, where exploring alternative worlds based on different laws is a serious branch of cosmology. Thought experiments of alternate worlds also have a long tradition in philosophy, e.g., Hilary Putnam's famous Twin Earth. However, these thought experiments or the many fantastical scenarios in fiction and art never left the stage of verbal description or depiction. Now the time is ripe to implement them in virtual worlds to be able to experience what it would mean to inhabit such a world and act within. The most recent examples giving us a clue of what might be possible are science-fiction movies such as "Inception" (written and directed by Christopher Nolan, 2010), in which 'virtual' worlds are created in order to serve as backdrop for dreams.

However, so far only very few developers of virtual worlds seem to go as far as abandoning Euclidean geometry: apart from the authors of the scientific study mentioned above, [5] Alexander Bruce is one of them. He is the developer of the yet to be released computer game Antichamber [8] that, according to his website, aims to be a "Philosophical First Person Single Player Exploration Puzzle Art Game" (Figure 2).

Physics as concept

From an artist's point of view, the whole story is completely different. Just as the potential of virtual worlds for scientific research has been emphasized repeatedly, there is an equally large potential for artistic discourse. But just as any other artwork, art using virtual worlds does not need to respect any boundaries, principles, or rules, and may even be more potent when those boundaries are violated. There are many examples in art history, specifically in the last century, where breaking the boundaries was an inherent element to successful artwork. To avoid misunderstandings: artists have, probably with few exceptions, never respected the laws of physics in their work. But that is not the point. Rather, artists so far could hardly use physics, and here we mean the physical laws and constants, as a *changeable medium* of their work, because they did not have the possibility to modify anything about it. Even though artists such as the sculptor Richard Serra or the installation artist James Turrell may count as an exception in their explicit treatment of physical topics such as gravity, balance, and light, it only is now that an artist could design a new system of physics, be it consistent or not, and have visitors come and feel what it means to be inside such a world. The approach may be compared to 'environments' [9] in installation art or participatory performance art. This interaction between the work and the viewer, while present in all works of art, has a specific immersive quality in such environments, which effectively resembles the non-verbal dialogue between artist and viewer in performance art, especially if it demands participation. In both the installations and the performances, the visitor is not just viewer but active participant experiencing the real emotion rather than just being confronted with its representation. Consequently, work such as the 'participatory objects' of Robert Morris (Tate Gallery, 1971) explicitly form an environment in which the visitor becomes the actor of a performance. The same holds for visitors of virtual worlds: as soon as they enter and interact, they become part of the work and as such performers within an environment.

If we understand the physical laws as instructions underlying the universe, then we can see *physics as concept* in the sense of conceptual art. One of the most influential texts on conceptual art [10] explains that "The idea becomes a machine that makes the art." Physics is the idea that makes the universe. And if the physical law was an artist's idea, the resulting universe is art.

References and Notes:

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