About Digital Reality Theory

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Digital Reality (DR) theory can be summarized in a seven-word sentence: "*Life understands existence by constructing digital realities.*"

A hundred years ago most people would have found this sentence incomprehensible, yet today its wording sounds commonplace. It took three intellectual developments during the nineteenth and twentieth centuries—evolution, set theory, and digitization—to achieve that change and to make DR theory possible.

- During the second half of the nineteenth century, **Darwinian evolution** theory recast many ideas about life. Among them was the idea of fixed knowledge. Thinkers such as Newton and Kant had searched for the principles behind the development of knowledge—Newton picked mathematics and Kant picked reasoning—but it never occurred to them that life itself evolved and that knowledge grew naturally with it.
- **Axiomatic set theory** was developed during the 1920s. In 1874, mathematician Georg Cantor had launched set theory by showing how to construct sets of numbers as real mathematical objects. A generation later two logicians, Ernst Zermelo and Abraham Fraenkel worked out the general rules for constructing sets of elements of any kind and for verifying that the sets were real objects.
- **Digitizing** as an information technology originated in the 1950s. While computers evolved from number crunchers to multimedia processors, their designers invented algorithms for converting analog data to digital form. The science of analog-to-digital conversion was born.

The latter two developments can be seen in today's smart computing devices, which construct sets of digital bits internally to represent external analog phenomena such as images, sounds, events, and even whole artificial realities.

DR theory analyzes the effects of these developments on the foundations of science. It is based on existing information and explanations and does not depend on any unpublished experiments or hitherto undiscovered truths. However, it does bring together ideas and trains of thinking that are not usually associated. It assembles a coherent and believable mental picture out of principles that have traditionally been scattered among various scholarly disciplines. Whether that picture is "true to life" is a matter of judgment in which you are the judge.

Life and Existence

The subject of DR theory—life understanding existence—covers a lot of ground.

- **"Life"** includes all living things on planet Earth, from bacteria to rock stars, plus their "footprints"—all the artifacts and environmental changes they make. It also includes some semi-independent parts of living bodies (such as mitochondria) and many groups of living things (such as species and societies). I mean by "life" everything in physical existence that manifests or is a consequence of, the reality of being alive.

  For example, an individual beaver is part of life, but so is the genus *Castor* and so are the dams and lodges that beavers build. During its lifetime, each individual beaver constructs a digital reality to help it build dams across one or more particular streams. *Castor,* the beaver genus, constructs a more general digital reality to help all beavers cope with all streams. The individual beaver stores its digital reality in its nervous system; *Castor* stores and transmits its reality in the beaver genome. Long ago the class *Mammalia* added to that genome a digital reality of urges and signals that helps *Castor* and other large animals reproduce; and so on. If you are a beaver, successfully behaving like one depends on having access both to the digital realities that you have constructed during your lifetime and to the genome that your species has constructed and corrected over millions of earlier beaver lives.

- **"Understanding"** is a defining process of life. Only living things do it. If my car won't start, I may say "It doesn't work." If my dog fails to obey a command, I am more likely to say, "He doesn't understand." Attributing understanding to living things goes far down the range of life, as when we say that ants understand where the sugar is kept.

  In DR theory, the result of understanding is called knowledge, even if the understanding is poor or incorrect. Knowledge is something that only living things can have: it shows up as a disposition to act one way toward some part of reality and not another way. Many philosophical systems mix up knowledge with truth, calling untrue knowledge "belief." This may work for humans, but it becomes awkward when applied to simpler creatures. For example, amoebas avoid direct sunlight because their genome knows that too much heat is usually unhealthy, but it would not add anything to our understanding of that fact to analyze it in terms of true or untrue beliefs. Consequently, most people have no trouble saying that amoebas know to stay out of the sun.

- **"Existence"** comprises everything. Yes, *everything*—ships, shoes, sealing wax, cabbages, and kings. It includes digital realities too, which living things construct as parts of their bodies. If a living thing wants to understand something, that something, by definition, must exist in some form. Contradictory things, such as the square circle of introductory logic, may exist only in someone's mind, but they must exist somewhere for us to try to understand them. That somewhere is digital reality. As Picasso once said, "Everything you can imagine is real."

  The problem with existence, so defined, is that we don't understand much of it. It is there, it affects us, we notice it, but we don't understand it. To understand it we need to build a kind of reality narrative in which what we experience is explained in terms of distinct objects and events. If you have ever watched a baby, you will appreciate how it struggles to sort out the world around it, to figure out what is what and how this interacts with that. DR theory posits that this process of reality building never ends. It says, in a sense, that we never fully grow up.

Constructing Reality

The goal of DR theory, therefore, is to explain how life on Earth, in all its forms and manifestations, accomplishes the task of understanding existence, which comprises both life and every object or event with which life interacts. The answer—constructing digital realities—sounds a bit mechanical. Isn't life about imagination, hope, love, and a lot of other intangibles? Yes, it is, but these are all parts or products of knowledge. DR theory goes a level deeper and asks how knowledge, in general, is acquired and stored, as well as what its boundaries are and what its future might be like. To answer those questions we need to interpret the last three words of the DR theory summary, "constructing digital reality."

• **"Constructing,"** as DR theory uses the term, is another activity (like understanding) that only living things do. The theory further specifies that the result of every construction is a set, as defined by axiomatic set theory. What is a set? It is a group of things, called "elements," identified together as a single object. A knife and fork taken together can be a set called a "place setting." The knife can also be a set whose elements are a blade and a handle. Putting a blade and a handle together to make a knife is an act of construction, one that originated among humans more than 5,000 years ago.

When you construct a set you understand a collection of things as a single new thing. Curiously enough, this simple operation was not recognized as a basic unit of human thought until nearly the end of the nineteenth century. Today it is deemed to be part of the foundational logic of mathematics and much more. Supported by a consistent set of axioms, set theory is as close as we have yet come to the ultimate basis for human thought. More practically, it is also an essential logical tool for computer programming.

Every set is different in kind from any of its elements; this is the crucial fact it took logicians so long to recognize. A knife is not another kind of blade nor is it any sort of handle: it has its own unique reality. It also can belong to category sets in ways that blades and handles do not—it's a tool, a weapon, a part of a carving set, and so on.

By analyzing digital realities in terms of sets, we can bring axiomatic set theory on board as the logical foundation of DR theory. This makes sense because the primitive ideas of DR theory are easily described as sets or elements of sets. For example, parts of existence become the elements of digital reality sets and digital category sets become the building blocks of understanding. Set theory helps us arrange our knowledge in ways that are both meaningful and useful.

• **"Digital"** is contrasted to analog. In DR theory, both terms denote a specific characteristic of the world around us. This characteristic is so basic that DR theory uses it as the primary separator of reality from the rest of existence. Existence is analog, and we experience it—it affects us—but we don't really know it. Reality is digital, and it's what we know when we say we know the world. As a consequence, converting analog existence into digital reality is a constant preoccupation of living things.

What makes raw analog existence and constructed digital reality different? One common answer is that an analog world is continuous while a digital world is discrete. From life's viewpoint, knowing a region of analog existence can be a never-ending process, whereas knowing a part of digital reality can be quickly and certainly completed. Since life is mostly about making decisions about the world around it, this makes digital knowledge more efficient and useful.

If you are familiar with computer science, DR theory will ring a bell. "Constructing digital realities" is what modern computers do. There is even a verb, coined in the 1950s, to describe how data is prepared for entry into a computer: it is "*digitized.*" All the analog data that a smartphone or desktop computer processes have been digitized into bits so the device can "understand" it.

Although professional philosophers have been slow to realize it, the development of digital computers has opened new vistas for epistemology. Computer architects are specifically tasked to design mechanical systems that understand and work with the world the way humans do. The payoff for philosophers is that we invented computers and understand how they work. The same cannot be said for human brains. By mining the trials that led to computer designs we can uncover philosophical truths about the workings of human knowledge.

• **"Reality"** is the totality of what living things understand. We and other living things constantly interact with existence, but to understand those interactions we construct and know realities.

For more convenient analysis, DR theory talks about many separate realities, each of which is a repository of knowledge. For example, the theory recognizes that a beaver constructs and maintains a reality that represents the dams it builds, while a human living nearby will construct a somewhat different reality about the beaver's handiwork.

Reality, constructed by life, is also new existence. It's the part that life can understand. Imagine a beaver confronting a flood that threatens to wash away its lodge. The beaver is not a hydrologist—it experiences the flood mainly in analog terms, as a set of existential threats. But the beaver is a builder, so it also understands how to meet those threats with a reality of digital sticks and branches. In effect, the beaver deals with existence by adding reality—an understandable construction of new existence—to it. That is life's typical response.

We, humans, are a bit more sophisticated when dealing with a flood. We start by measuring it, something the Egyptians have been doing for 5,000 years. Measurement creates a digital reality—water so many feet deep, an object we can understand. We can then figure, in digital terms, what we must do (if anything) to counteract the flood. The beaver's innate measurement of the floodwater produces only a 1-or-0 binary number that measures "too high or not too high." Ours produces a more complex number that measures how high, but the effect is the same.

One way to characterize DR theory is that it tries to update our formal knowledge—knowledge taught in universities—by incorporating in it all we have learned during the twentieth century about biological evolution, axiomatic set theory, and multimedia digitization. The next sections discuss some of the results of this updating.

The Evolution of Knowledge

Living things survive in existence because they know how to extract energy from their surroundings and use it to build and develop themselves. The knowledge that makes this possible can be organized in various ways. DR theory traces the evolution of three kinds of practical knowledge:

- how to organize living behavior using time
- how to arrange physical objects using space
- how to use ideals to recognize patterns in reality

DR theory limits its definition of life to what is observable on Earth; it also accepts the current scientific view that Earth was formed about 4.5 billion years ago and that life arose about half a billion years later. Since knowledge is needed for life to exist, then the evolution of knowledge must have started about 4 billion years ago as part of the evolution of life.

DR theory posits that **time** order is the skill on which terrestrial life was founded. What role did time play? First and most importantly, it enabled heredity. Organisms acquired modifications that increased their ability to survive and then—later in time—they managed (by means currently unclear) to replicate themselves, passing their improvements to new organisms. Otherwise, they perished and their skills were lost. A digital time sequence of change followed by reproduction was essential to this process and was also something new in existence. Its emergence in early organisms made part of life digital and detached it from raw analog existence.

Time sequencing must have enabled metabolism, which is based on repeatable chains of chemical reactions. Energy transfer using adenosine triphosphate (ATP), which is universal in life today, must have appeared early. The current Krebs cycle uses more than 30 ATP transfers, interleaved in a specific order with other reactions, but at first, there may have been fewer. The point is that without digital event sequencing no such process as metabolism would have been possible in analog existence.

In DR theory, time is the simplest form of digital set construction. It forms countable sets of Cantorian cardinality aleph-zero—linear sets that accept new elements at only one end. You can visualize such a set as like a bookshelf where you can add new books to the end but you can't slip them among the books already shelved.

Ordering physical knowledge in **space** may have become an early life skill to support DNA-based reproduction. An organism that knows only a time dimension may reproduce itself by fission; but to establish an evolving genome, the organism must create a set of coded instructions for building new creatures. Life's crucial breakthrough was the development of the DNA molecule, which stores sequential instructions by representing time spatially. By "reading" codons—groups of amino acids strung spatially along the length of DNA genes—an organism can execute the time-sequential digital actions necessary to manufacture proteins. The positions of certain codons in one dimension of space represent the serial steps in time required to synthesize each specific molecule.

A digital reality with one dimension of space is adequate for reading DNA as well as for feeding oneself by random encounters with organic and inorganic molecules. But around 3 billion years ago, life on Earth achieved an evolutionary breakthrough in photosynthesis. At the time, a few phototrophic microbes could capture energy from sunlight, but they did so inefficiently and did not extract carbon from the environment. Solar photosynthesis ultimately evolved into a versatile chemical factory that uses the energy in sunlight to break carbon dioxide and water into their elements, while synthesizing a variety of useful organic molecules on the way and filling our atmosphere with oxygen.

Life's use of solar energy may be responsible for additional spatial dimensions in digital reality. Sunlight comes from a single distant source; it rewards organisms that can locate that source and collect the sunlight on large surfaces orthogonal to its vector of propagation. Why three spatial dimensions? If sunlight had been like lightning, striking Earth at single points, the organic structures that captured it could have been one-dimensional, recognizing only up and down. But the sun shines best on horizontal surfaces, requiring a minimum of two non-vertical dimensions to describe an effective collector. From an organism's viewpoint, moreover, sunshine falls not in discrete lumps but continuously and indivisibly, so the set that describes its collection space cannot be linear, like a set of time-ordered behavior; it must be a Cantorian set of cardinality aleph-one. To extend the bookshelf analogy, space is like a library to which you can add a new book wherever you want.

Life could have evolved any of several combinations of time and space dimensions to organize its digital knowledge. But consider that life on the surface of the Earth is whirled about in a complex motion with respect to the sun—a cycloid curve compounded from our planet's orbital speed of 67,000 mph and its rotational surface speed up to 1,040 mph. To maximize the ability of primitive photosynthetic organisms to track the life-giving sun from such an itinerant platform, the relationship between time and space that life evolved had to be such that the four-dimensional vector of propagation of radiant energy remained constant as life moved about it. Einstein intuited the truth of this invariance—equivalent to saying that the speed of light is the same regardless of the motion of its observer—but he regarded it as a given feature of existence, not as a product of biological evolution. DR theory explains why it is so, whereas relativity theory must assume it as a postulate.

What DR theory calls **ideals** are life's latest evolutionary development. They are the universal patterns that philosophers call *a priori* plus the abstractions that make organisms clever as well as adaptable. In the language of set theory, ideal patterns are found in the *powersets* of physical sets. A powerset is the set of all possible subsets of a set. In effect, it provides an inventory of all the ways the elements of a set can be associated with one another. When spatial ordering provided life with a way to preserve recipes for survival, ideals emerged as a factor in evolution. By revealing all the possibilities of manipulating the physical world, they helped both species and individuals solve problems more efficiently than would be achievable through trial and error.

At the simplest and oldest levels of living evolution, the actions of organisms can be understood in terms of time-ordered reflexes, urges, and needs. At the next higher level, physical objects ordered spatially become factors in life's understandings—habitats, environments, ecosystems, etc., as well as human artifacts. At the top level, we must call on ideal patterns such as goals and strategies to understand how life survives as it does. DR theory also shows how the complexity of human life is attributable to our ability to be informed and guided by ideal categories. They provide inventive alternatives to emotional reactions and physical pressures. Besides deepening our understanding, ideal patterns form the basis for much of our social and communal lives. They make us the most creative (and also the most troublesome) animals on Earth.

Orders of Reality

A major consequence of the evolution of knowledge has been to divide the digital realities that we humans build into three disparate orders:

- Time-ordered **behavior** comprises our private inner perceptions, thoughts, and emotions, plus the motivations that lead to our outer conduct. It is tempting to treat living behavior as just a complex kind of corporeal mechanics, but DR theory, using set analysis, recognizes it as wholly separate from physical activity.
- The **physical** world includes the natural cosmos, our bodies and actions, and the tangible artifacts we make, all arranged in space. Some materialists argue that this is the whole of reality.
- **Ideals** are the values, universals, and abstract principles that tend to guide our behavior and also help us communicate and argue with one another. Philosophers have a long tradition of treating ideals as truths independent of the physical world.

Distinguishing three orders does not fracture digital reality into Cartesian mind-matter dualities, because the three are joined together through set operations. In technical terms, physical sets are powersets of behavior and ideal sets are powersets of physical sets. Empirically described, human behavioral experiences lead us to construct physical reality, which we then understand through ideals. Set theory not only shows how digital information flows through this hierarchy, but also explains why we find behavioral, physical, and ideal realities to be so different in kind. They cannot be compared element-by-element because their sets have different cardinalities, as Cantor discovered about mathematical sets 150 years ago.

The main payoff for distinguishing behavioral, physical, and ideal orders of reality is that digital sets in each order can represent either object of knowledge or categories that describe those objects. In behavior, the result is consciousness; in physical reality, the result is the rich mass of digital data that comprises human knowledge. With three orders of reality to choose from, an object in one order can be categorized by sets in either of the other two orders. In science, for example, physical events can be categorized by ideal laws, as physicists do, or by behavioral observations, as biologists do. Moreover, this choice extends to all human realities, not just to academic studies. To regulate the physical actions of members of a human group, its leaders can choose either ideal laws or behavioral dictates. Laws are typical of modern democracies; dictates are more appropriate in smaller groups, such as families. The books I have written discuss this digital “cross-categorization” effect at length.

Analog-to-Digital Conversion

During the last few decades, the words “analog” and “digital” have migrated from fairly specific terms in electronic technology to trendy labels for everything from photographs to lifestyles. When digital computers were first designed they processed digital inputs—switches, keyboards, punched cards or tape, etc. When a key was pressed or a pattern of holes was read, the computer converted that discrete action into a set of binary bits in an electronic register designed to store binary numbers. For example, pressing the R key on a Teletype keyboard entered the five-digit binary number 01010 into the computer. This pattern of bits (as binary digits came to be called) represented the Roman letter R in Baudot coding. After processing, the output might be rendered by punching holes into a paper tape, five rows across, which a Teletype printer could sense mechanically and type out as readable text.

At the time, there also were analog electronic computers that accepted analog inputs. These inputs were usually varying electric voltages, but the voltages often represented other quantities—temperature, pressure, the level of liquid in a tank, etc. The inputs were called “analog” because the voltages varied as analogs of the quantities they measured—0.1 volt for every degree Fahrenheit above 0, for example.

Digital processing quickly won out over analog processing, for several reasons: analog signals tend to degrade as they are carried in wires, they are difficult to store, they need regular recalibration, etc. A demand is built up to convert quantities into digital bits at their source and then deal with the data digitally from thereon. But sensors, such as thermocouples and strain gauges, tend to be analog by nature; it is hard to design a device that converts temperature directly into a number. Thus was born the analog-to-digital (A/D) converter, a device that measures a varying electric signal and reports its voltage or frequency as a pattern of digital bits.

Any computer engineer will tell you that A/D conversion is never fully complete nor absolutely accurate. It can also follow many different algorithms, producing different and incompatible digital outputs. When computers communicate with one another, they are careful to specify their digitizing methods—that’s where file tags such as .pdf and .aiff come from. For example, computers have used any of three different techniques to digitize two-dimensional graphic images:

- Vector graphics analyzes the image into points connected by various kinds of lines and fill patterns, all using a repertoire of drawing instructions identified by binary numbers.
- Bit mapping divides the image into pixels—tiny dots usually arranged in a rectilinear grid—and assigns a binary number from a palette of standard colors to represent the color of each pixel.
- Library techniques, such as OpenGL, decompose the image into a collage of generic shapes with added size and color information. Each generic shape has a binary ID that calls the code required to render it from a digital library stored in the computer.

Notice the association of these techniques with the orders of digital reality, described above. Vector graphics are like drawing instructions for a behavioral computer, bit mapping is like a two-dimensional map of physical reality, and library programs assemble images from ideal shapes.

Examples of Reality Construction

What is it like to "understand existence by constructing a digital reality"? For an illustration, let's go back to cathode ray tube (CRT) television sets as they existed before flat panel displays were introduced in the 1980s. In a CRT, the picture is painted by a moving dot of light—one dot for black-and-white, three dots for color. The dot, its intensity varying in response to an analog signal, zips back and forth like a tractor plowing a field. It draws a complete picture thirty times each second, and successive pictures convey motion by their frame-to-frame differences. To suppress motion blur, high-quality CRT phosphors usually have minimal persistence: the dot on the screen is lit only briefly at each position, while the dot-writing beam swings a millimeter or so to the next position.

At any instant, what existed on the face of the early TV screen? A dot of light of smoothly varying intensity. Yet people focused on that little analog dot, enthralled. They saw the Beatles, they laughed at Lucille Ball, they watched a man walk on the moon. What they saw and understood was not a dimming and brightening dot roaming back and forth, but the digital objects that the TV was designed to present—people, things, discrete events. Because their vision did natural analog-to-digital conversions, viewers understood an analog dot of light in terms of a bitmapped digital reality that they constructed in their minds.

A technology I have worked on, the head-up display, demonstrates digital reality construction applied to the everyday world. You may have seen the helmet version of head-up technology in spy movies. The helmet wearer looks through a specially coated glass, called a combiner, that merges the view forward with collimated graphics from a computer screen inside the helmet. The result is digital information—typically numbers and text messages—merged with an analog view of existing objects, creating an enhanced reality. In the aircraft version, the combiner is located in front of the windscreen so the pilot looks through it while flying the plane.

The point of a head-up display is to add information that only a computer "knows" to the world as you normally see it. This serves the same ends for a human in a competitive society as keen hearing serves an animal in the forest or intelligence helps a crow. The current flood of smart "digital assistants" is only the beginning. The future trick will be to integrate digitally enhanced realities into meaningful daily life, instead of letting them just supplant life with gossip and entertainment.

Analog-to-digital conversion is not something only computers do. You can find it everywhere in living organisms if you know where to look. For example, the all-or-none law of neurophysiology, first enunciated in 1871, states that the strength of the response of a nervous system component is normally uniform and independent of the strength of its stimulus. Stimuli above a threshold level cause full responses; stimuli below that level cause no responses at all. This effect, which happens at all stages of biological data flow, constantly filters out analog noise and maintains information in purely digital form. Living non-neural chemical systems, particularly in plants, can be equally selective: cell membranes and molecular receptor sites pick and choose molecules as existence presents them, absorbing only the ones with useful digital characteristics.

Verifying DR Theory

How can DR theory be verified? Many theories cite crucial experiments or broad-scale studies as proofs of their validity, but philosophers have pointed out how such demonstrations only show that a theory is useful, not that it is absolutely correct. DR theory is in that position. Its confirmation depends on how well it helps us understand the world, not on how accurately it calculates measurements of physical quantities.

DR theory also bears the burden of being fundamentally dualistic. Ever since Descartes championed mind-body dualism (which could be reconciled with the deism of his time), philosophers have been spooked by an ontology that involves multiple divisions in reality. The problem with such systems boils down to answering the questions “In which of multiple worlds do we truly live?” and “How do we access another world from the world we are in?”.

To these questions, DR theory offers simple and believable answers. We truly live in an analog “existence” that affects us and other living things and with which we interact. When we want to understand and work with that world, however, we access one or more digital worlds that we have constructed, which DR theory calls “reality.” Life has spent 4 billion years making our digital realities represent analog existence, having developed time, space, and categorization among our more basic tools. Understanding digital reality is the primary way we know anything.

These answers may raise a further question: If the analog-to-digital conversion is the secret of life and the key to understanding existence, why haven’t philosophers been talking about it during the last two thousand years? DR theory’s answer is again simple: until the invention of multimedia computing, scarcely fifty years ago, no model has existed to show people how global analog-to-digital conversion might work. It took the work of computer engineers to demonstrate how digital realities might be constructed. Today we not only use electronic realities in our daily lives, but we have also developed an axiomatic set theory to expose their underlying logic. We are no longer forced to depend on the mathematical analysis of analog quantities to understand the world in which we live.

Finally, some may object that DR theory replaces hard external objectivity with a potentially arbitrary reliance on mental modeling. The answer—again from the findings of computer technology—is that digital data is demonstrably more accurate, more durable, and more usable than analog data. That is why it has evolved as the choice of life and has become the legacy of mankind. Because we cannot find digital data in existence, we are justified in creating it for ourselves.

Astrophysicist and science popularizer Arthur Eddington once composed an image that I feel evokes the message of DR theory. “We have found a strange footprint on the shores of the unknown,” he wrote. “We have devised profound theories, one after another, to account for its origins. At last, we have succeeded in reconstructing the creature that made the footprint. And lo! It is our own.”