Toward a Unified Multidisciplinary Model of Reality

Abstract

Over the last several centuries, science has discovered objects in the world along a continuum of scale. In one direction, we have discovered planets and stars, as well as galaxies and galaxy clusters. In the other direction, we have found cells and proteins, atoms and neutrinos. To locate and model this world, we use the 3 traditional directions of length, width, and height. However, inherent in all our measurements is the scale of what we are measuring – a continuum we do not directly see with our eyes. The author presents the hypothesis that we need to include this continuum in a complete model of nature and our world. Why we have not already included this continuum can be traced to our lack of mathematical tools to handle the exponential structure of the measure of scale. The author presents the mathematical conjecture that the appropriate tools require a numeric representational system with more power than our traditional decimal or positional-based numerals. Such a system could provide a single value for complex numbers and make possible measurements currently invisible to science today.

Keywords: Philosophy of Science, Scale, Dimension, Numeric system, Complex values

1. Overview of Philosophical Discussion

In general, science has broken into levels of study at one or another level of scale to consider the objects and processes found at that level. Thus, we have particle and atomic physics, molecular and protein chemistry, mitochondrial and cellular biology, bone and organ medicine, ecological studies, meteorological and atmospheric studies, solar system studies, star systems and galactic studies, and large-scale astrophysics. These are all important areas of scientific study; however, each level tends to have its own characteristics, objects, and interactions along with its own measurements and equations.

Physical models tend to limit themselves to specific levels of scale, even though multiple levels are observationally relevant. Multi-scale modeling is explicit in attempting to address several levels of scale. There are published articles attempting to include scale in many areas of science today, including for biological processes, including Berman (2018), Sulpizi (2018), in geology and geophysics including Stewart (2022), van Oosterom & Stoter (2012), and in complexity theory including Pavlos, et al (2011), Hoel (2025). Systems biology has become an area where interactions between multiple levels of scale are inherent in the methodology (Kohl & Noble 2009). Finally, some argue that understanding reality requires modeling the objects and processes at many scales as stated by Green & Batterman (2025).

The larger scientific enterprise, though interconnected, remains generally segmented into disciplines that tend to align along the levels of scale. Each discipline employs a mathematical model tailored to the scales it studies, and translation between these models is often nontrivial at best. From Green & Batterman (2025): "No single mathematical model can account for behaviors at all spatial and temporal scales, and the modeler must therefore combine different mathematical models relying on different boundary conditions." This stratification results in:

- Redundancy: Overlapping but incompatible models of similar phenomena.
- Translational friction: Difficulty integrating phenomena across scales.
- Missed phenomena: Emergent behaviors and cross-scale interactions may go unrecognized or unexplained, including the possibility for larger-scale processes to affect smaller-scale processes and objects.

The issues stemming from this stratification have made it difficult to unify all these levels. The reductionist attitude that all higher-level objects and processes can be explained via lower-level objects and processes belies the many levels we observe and the similar behaviors at macro-scale from distinctly different micro-scale objects. Batterman (2017) states it this way: "The problem is to explain how it is possible that systems radically different at lower scales can nevertheless exhibit identical or nearly identical behavior at upper scales". To address these issues, we need to provide a modeling space that crosses many levels of scale.

Scientists and philosophers have arguments over whether reality can be explained through bottom-up reductionist methods (the smallest objects determine reality) or whether top-down anti-reductionist methods are needed (e.g., Franklin 2021). This author believes both arguments obscure the continuum of scale that observations have presented us with. Reality is a whole and should be modeled as such, meaning we must include this continuum of scale in our models of reality, enhancing the drive toward multi-scale modeling.

This author presents the hypothesis that, given the many efforts to model objects and processes across scale, we need to explicitly include scale as part of our model of reality. This means scale is considered a physical continuum that we model as a physical (fourth) dimension.

This paper is not about overturning theories of physics or mathematics. It is about stepping back and considering the unification of many areas of scientific discovery into a single model of what we know of reality, then asking how this would impact our existing models and whether we have the appropriate mathematical tools used by science to handle this new model. The real thesis of this paper is that engaging in this unification will indicate new directions of study and discovery in both science and mathematics.

To make this next step, most of the particulars in either science or mathematics will require capabilities and efforts considerably beyond those of the author. The complementary theses are:

1) Scientific Hypothesis: We should consider a single model of reality where objects at all levels of scale are included and interact together. This will involve identifying the scale of all objects to locate them within the model and require a four-dimensional physical model.
2) Mathematical Conjecture: We will require the development and expansion of significantly more powerful mathematical tools that can adequately manage this model. We will need the ability to measure across a non-linear scale dimension. The mathematical conjecture is that this measurement ability will involve a more powerful numeric representational system to address combined linear and non-linear dimensional measurements. The author suggests the particular system should provide complex values as single numeric values that can provide measurements, using a single complex measurement value, not available today.

2. Generating a Single Model of Reality

The size, or scale, of objects in our world is a commonplace part of our experience. We perceive objects smaller than ourselves, like a pin, and objects larger than ourselves, like a building. For centuries, our perceptions have not gone beyond what we can directly experience through our five senses. The Greeks may have hypothesized atoms, but they could not perceive any such objects. Only in the last few hundred years have science and technology shown us very small atomic particles and very large galactic objects. We cannot experience these objects directly with our five senses and need tools to perceive them. This world, expanded through technological tools, has become the directly and indirectly perceived world of science today.

We understand the scale of objects in this world to be along some sort of continuum – from the very small to our scale to the very large (see Fig. 1). This continuum has expanded several orders of magnitude just in the past century. What we consider to be the 'space' of our world has expanded accordingly. A key concern of this paper involves our model of 'space' and whether it adequately accounts for this continuum of scale.

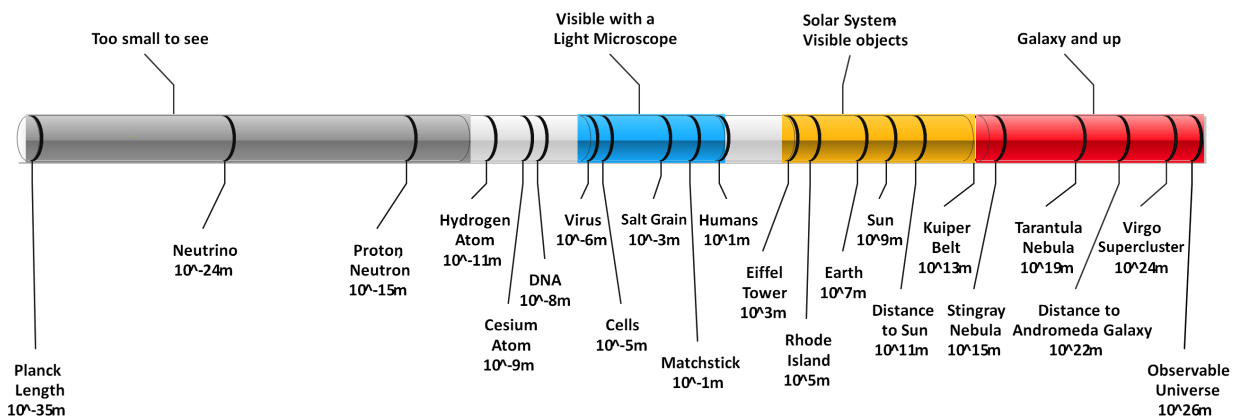

Fig. 1 The Continuum of Scale

Our geometric model of physical space has not changed over several millennia. We have expanded the objects we find in space by many orders of scale, yet we still hold to a three-dimensional model of space devised more than two million years ago. We still consider the only perceivable dimensions of physical space to be length, width, and height. This is a very human-centric perspective based upon our direct senses. We continue to think our millennia-old human-centric three dimensions are the only dimensions needed to uniquely locate an object in space.

Consider the observation that if we touch our finger to a pane of glass, the direct evidence is of our finger touching the glass. If we perceive the action with a magnifying glass, we will see specific ridges of our skin touching the less-than-smooth surface of the glass. If we perceive the action with a microscope, we will see cells touching the crystalline surface of the glass. We can continue indirect observations using different magnifying tools down to the protein and molecular scale levels. We could set up multiple observational tools to observe different scale levels during the same action, and we would gather the observational evidence that the action occurs at all these levels together, not one or the other. If science is about observations, then we should agree that nature operates as a cohesive whole, not at only one or another level. This allows us to include objects and actions at all levels in our new model as our observations indicate. To build a single model of nature, we need to include this 'scale direction' into our scientific models of nature.

If we are to efficiently model this one action of touching the pane of glass at all levels, we will need to be able to specify the actions at every level and then combine them across levels. Each level exists at a certain scale, with differing objects at different scales. Since we model each level as actions in a three-dimensional space, combining them as multiple three-dimensional layers would most effectively require a four-dimensional physical model, identifying the scale level as one of the locators in the modeled space (Fig. 2). This methodology would provide a means of locating a pen on a table, an atom of the pen, and a star in a different galaxy all in one model. It would not be limited by individual models at each scale, nor require squashing all levels down to a single (three-dimensional) level, say to calculate the distance between the star and that atom of the pen. Rather, it would require these individual models to be integrated across scales. Such a holistic model could allow for actions between levels, both upward in scale as well as downward in scale.

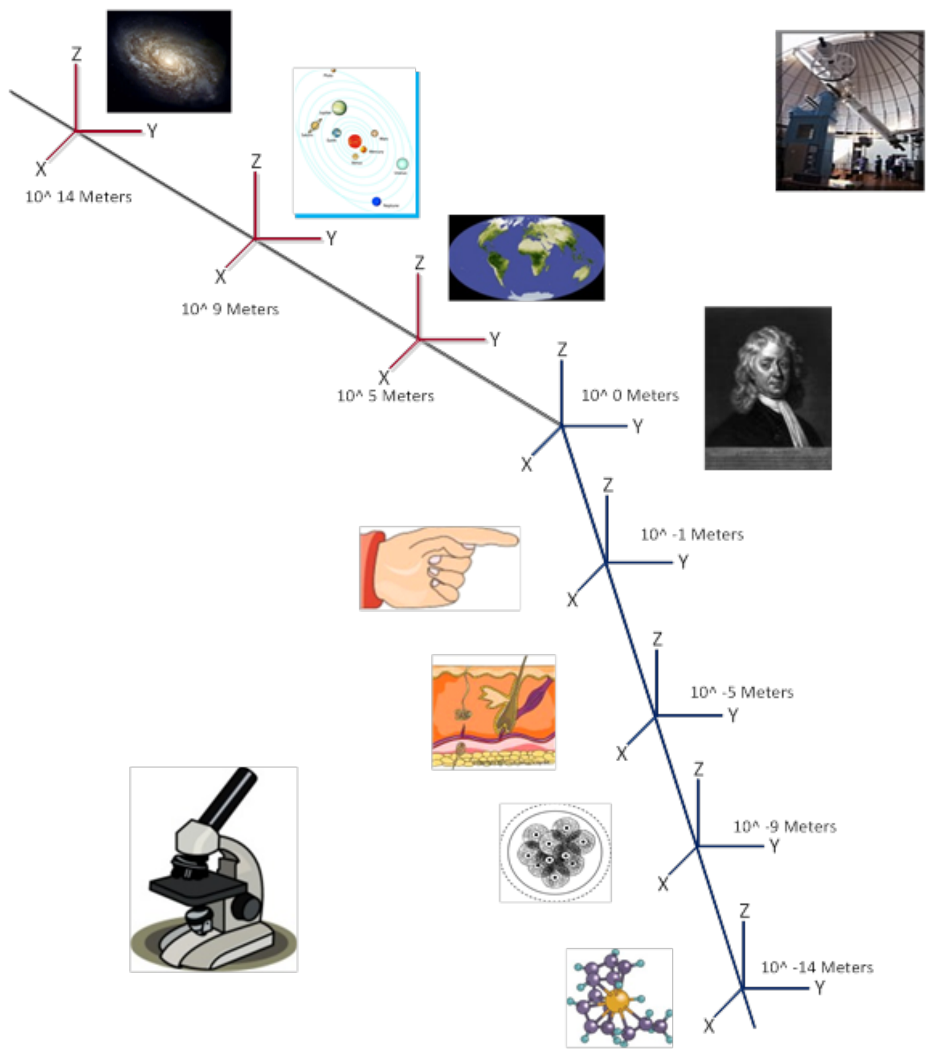

Fig. 2 The Hypothesis of Scale Space

3. Challenge for Scale Measurements and Mathematics

Underlying science is mathematics, which needs to provide the quantitative means to account for this scale direction of nature. Using the mathematical tools of today, how can we compare and handle interactions at very different levels of scale, where the error term at the higher level is larger (sometimes by orders of magnitude) than the measurements at the smaller scale? The author suggests that a key reason we do not include this direction as part of our model of nature is that we do not have the appropriate mathematical tools to handle measurements and activities that cross this scale continuum. The author introduces the conjecture that new mathematical tools will be required to adequately measure across and to manage the processes of this continuum. We will need a new method of representing measurement values that cross scale, which indicates we need a new method of representing numbers – a new (more powerful) numeric representational system.

There have been a number of appeals for new mathematics, sometimes involving issues of scale as by (Long 2001): "We need at least a comparable change of paradigms or conceptual and contextual dependence, we cannot easily draw their mathematics on the phenomenal veil by "cutting them off" from their context and by giving constructed contours. This, I believe, is the underlying methodological challenge for Mathematics in Biology, as Mathematics usually organizes the physical world, sets norms for it."

Adding scale as a dimension is a change in perspective of nature that does not (immediately) change our observations to date. Measurements at each level remain unchanged, so all current measurements and equations at one scale or another would remain intact. Interpretations of those measurements and equations might involve a cross-scale review. The above discussion about touching our finger to glass suggests modeling the many levels of nature using four spatial dimensions is more direct and potentially better than our traditional three-dimensional space, which still needs to account for objects at different scales. The implication is that 'space-time' as four-dimensional might not be a good model, perspective, or interpretation. (There might need to be a review regarding the interpretation of the four dimensions in the equations of gravity against this new four-dimensional model.) The hypothesis introduced is to expand space to four dimensions, and then we could tack time onto these four spatial dimensions – conceivably modeled as a five-dimensional 'space-time'.

a. Perceiving the Dimension of Scale

There are two classic videos of traveling across scale: *Cosmic Zoom* (National Film Board of Canada 1968) and *Powers of Ten* (Eames 1977), both inspired by Kees Boeke's 1957 book *Cosmic View: The Universe in 40 Jumps*. More recently is a 2011 book that looks at traversing the levels of scale by Gott, J. Richard, and Vanderbei, Robert J. *Sizing Up the Universe: The Cosmos in Perspective,* and a worthy interactive website, *The Scale of the Universe*, by the Huang brothers. These all provide a perspective of traveling upward and downward in scale, seeing different objects come into view at different levels of scale. They also give a feeling about how it would appear to travel through different levels of scale. Two things to note in all these videos (and books):

1) As we progress up or down, we see different objects (especially noticeable when progressing down). This is characteristic of travel in our normal three dimensions – we see different objects as we travel while looking at the same three-dimensional location. As the preceding discussions indicate, this implies a four-dimensional model of nature.

2) From a standard unit of length perspective, travel up or down in scale involves traveling in 'Powers of Ten.' One unit upward would be an increase of 10 of our 'standard units' and two units upward would be an increase of 100 of our 'standard units'. This means a linear movement in the scale direction involves a power (or exponential) change in the relative lengths we measure moving across scale. What this translates into is that a linear movement in scale will appear to us as an exponential movement according to our standard units of length. Such a movement may appear to us as an acceleration rather than a velocity, which could have many impacts on what we appear to perceive.

Noted in 2) above, while the hypothesis of including scale as a spatial dimension might seem a simple expansion of space to four dimensions, there is a key difference between our traditional 3 dimensions and that of scale. The measurements in our traditional dimensions are all equivalent – 1 unit (e.g., one centimeter) in any direction equates to the same unit in any other dimension. Our traditional three dimensions are linearly equivalent related dimensions. This is not the case with scale, which has a different measurement or metric. Relative to the units we use in our traditional dimensions, scale has an exponential measurement.

A couple possible interpretations of scale with an exponential metric could be that constant movement in only scale might appear to us as a constant acceleration on objects, even if the objects do not move in our three dimensions. Acceleration at the galactic scale could appear to us as expanding galactic space.

This relative exponential metric of scale is a challenge for mathematics rather than science. Traditional geometry assumes all dimensions of a space have the same units, with the distance between any two points in space defined by linear dimension measurements (e.g., distance = sqrt (x^2 + y^2 + z^2)). However, to model nature, we may need a geometry that does not have the same distance measurement, or metric, in all spatial dimensions. Since the position of objects uses distance measurements and the location of objects is key to science, we will need to address distance measurements across scale. For this, we will need to consider the mathematics we use for measurements in science, which bridges into the mathematical conjecture.

b. Measurements along the Dimension of Scale

There is an intriguing interplay between numbers and their representations. We have numbers and we have representations of numbers (or 'numerals'). It is simple to state that the representation of a number is not the same as that number. However, the two are intimately connected, and we could argue that only by some representation of a number (even if verbally or by show of fingers) could there be the concept of number in the first place. Early humans had marks on a stick or a papyrus pad. Romans invented Roman numerals, and Greeks used a version of fractions for ratios. All these involved representations for numbers in order for them to be utilized and communicated. Note that this discussion is not about the type of abstract numbers we refer to – such as Integers, Rationals, Reals, or Complex. It is about how these numbers are represented and manipulated as values and measurements. We could state that numerals are critical to the development and application of numbers.

Consider that current science would not be possible without the decimal (and positional) numeric system we use to represent numbers today (Tobias 1954). The author submits that a system such as Roman numerals is completely inadequate for the measurements of current science. Fractions are, likewise, not up to the task of capturing measurements and providing the arithmetic for equations defining scientific laws today. Measurements on the quantum scale would not be possible using fractions or other limited numeric representational systems. A strong statement could be: Without our current method of representing number values – particularly for measurements – we would not have the science of today.

The decimal numeric system became the defining means of representing numbers and measurements less than a thousand years ago. Its use predates the explosion of science in the last 400 years, lending support to the idea that current science needs such a representational system to manage the measurements of today. We cannot manipulate nor measure or calculate quantities without numeral systems. And, as implied above, the power of science has a significant dependency upon the power of the numeric systems used (e.g., decimals vs Roman numerals). This provides a view into how deeply science depends upon our numeral systems – it is at a very foundational level.

If defining the position of any object is only a question of accuracy in a 3-dimensional world, then we should have no trouble measuring the distance between any two objects in nature. But how can we measure the distance between objects at very different scales - say from a pen on the table to a molecule of the table? There is a large difference in the accuracy, or error term, of a measurement, say in meters for the position of the pen and in nanometers (meters * 10^{-9} or .000000001 m) for that of a molecule. To compare measurements made at vastly different levels of scale, we need to be consistent and use the same units and scale for the measurements. However, using units at our scale provides an accuracy, or rather an error term, that is many times larger than the measurement of the molecule (e.g., 0.436 m ± .001 m for the pen and

.00000003.1 m ± .0000000001 for the molecule). The level of accuracy (or error term) on the measurements at the different scales does not match up and is therefore not compatible. While some might say this is 'just how measurements work', the author suggests this shows the inadequacy of our current system of measuring values to address differences in the scale of objects we find in our world.

It could be that anomalies in our current scientific models are a consequence, not just of an inadequate model, but of inadequate mathematical tools to build a better model. There is a saying: 'If all you have is a hammer, everything looks like a nail.' Consider if the mathematical hammer we have is our decimal (or positional) numeric system, which can handle Real numbers that fit on a continuum (the Real number line). We will see all continuums as Real ones that can be entirely handled by decimal (or positional) numeric values. If we come across something more than this, such as complex values, we couch such a different tool in terms of the hammer we know – Real numbers that have decimal values. We do this with complex numbers, breaking them into two parts, each of which involves a Real value (e.g., x + iy). In expanding our concept of space, we may also need to expand our measuring tools at a basic mathematical level.

If our scientific hammer is three-dimensional space and our mathematical hammer is the decimal numeric system, what might occur if the mathematical hammer affects, even causes, the scientific hammer? If we are unable to represent certain mathematical values, then we might also be unable to represent certain measurements in nature and therefore we could be missing aspects of nature we endeavor to study (such as cross-scale distances). Part of the mathematical conjecture in this paper is that a more powerful numeric system could provide more advanced scientific theories than we have today – we need new hammers in both disciplines.

If we are unable to adequately compare and relate measurements at significantly different scale levels, then there are limits to our current measurement tools. If we are unable to properly measure across scale with our current tools and we agree that differences in scale constitute distances in scale-space, then we have identified an aspect of our new four-dimensional model for which we do not have the mathematical tools to measure. At a time when the reigning philosophy is to only consider what we can measure, we have hit that uncomfortable situation that might be stated as "we don't know what we cannot measure," and we have now identified aspects of nature we cannot measure.

4. Finding Adequate Measurement Tools – Advanced Representational Numeric Systems

Our simple whole numbers can be defined using a basic unit (one) and the operations of addition and subtraction. This is how we represent the Integers, including negative whole numbers. Examples include: 1 + 1 = 2, 4 + 1 = 5, and 2 – 3 = (-1). Fractions are defined using integers plus the reversing operations of multiplication and division. This is how we can represent the Rational numbers as ratios, which include the Integers. Examples include: ½, 2/3, 4/4, 47/35, -5/7, 13/93762. Positional base numerals, like decimals, add the reversing operations of exponents and logarithms to represent Real numbers, which include the Rationals. An example of how we build up a decimal is: 5x10^2 + 1x10^1 + 2x10^0 + 3x10^-1 + 6x10^-2= 512.36. Using these three pairs of reversing operations, we have a representational system that can theoretically represent all Real numbers, although infinite decimals present a practical limitation. Note that in all three cases, we have defined a specific value for each Real number that can be used as a quantity or measurement and in calculations.

While simple numerals, primarily for small counting numbers, have unique representations for each number, fractions are not the same, as there can be an infinite number of ratios, and therefore of numerals, to represent the same Rational number (e.g., 1/3, 2/6, 3/9...). Transitioning to decimals, we find that these numerals may not be as precise as fractions, since the fraction 1/3 is exact while the decimal equivalent is 0.333… - a representation that can only approximate the same fractional value. Further, adding two fractions and two equivalent decimals, we get 1/3 + 2/3 = 3/3 = 1. However, using decimals, we have 0.333… + 0.666… = 0.999… = 1.00(?) So we must make 1.000… = 0.999… for the arithmetic to work. Even with decimals, we have the situation of two numeric representations for the same number value.

It is important to understand that representations of numbers have characteristics and limitations that are not true for the numbers they represent. This aspect may be especially important if we are unable to adequately represent a number as a single value, such as a complex number. By not accounting for the limits of our mathematical tools, our models may be missing measurements our tools cannot address. This would be the situation with how we currently represent complex numbers. We are unable to represent a complex number as a single value that could be used as a measurement, so we manage with what we know and represent a complex value using two Real numbers: x + iy. However, this means our models cannot account for measurements of single complex values (i.e., that require a value for ‘i’).

Ignoring the entire imaginary part allows many theoretical calculations involving measurements to produce different complex values yet result in the same real quantity (5 + yi equates to the Real value 5, regardless of what ‘y’ or ‘yi’ are). This is a logical problem for physical theories, since calculations in a theory could produce different complex values, yet the calculations for the theory would have to reduce to something we can measure and represent as a single value. Even if we account for ‘y’, we still cannot account for ‘i’ and thus cannot identify what a single complex value looks like, let alone what it could measure. We are left with two separate parts of a complex number that we can only evaluate as two parts. Five and π are understood as a single value and can be used in measurements and calculations as a single value. Not so with complex numbers – as we represent them today. If the currently accepted scientific philosophy is that all we can know of the physical world is through measurements, and we realize that our numeral systems are not capable of entirely specifying all practical quantities, then we have a direction to investigate before any scientific theories can be considered complete.

On the theoretical mathematics side, we have become used to understanding complex numbers as 2-dimensional numbers. This situation appears to have 'gelled' into the idea that this is a property of the complex numbers. However, as noted previously, our numeric representations have aspects and limitations that are not true of the abstract numbers they represent. This might very likely be the case for the numeric methods we use to represent complex numbers. We only know how to represent them as 2-part decimal (or Real) numerals that involve an always unknown value ('i'). We are unable to resolve the imaginary part into an actual numeric value, and so we leave it apart – unresolved.

We should note that science uses complex numbers for many calculations and equations. Our numeral system for representing complex numbers theoretically appears to produce unique values for all complex numbers. We use complex numbers for all sorts of calculations, but because we cannot resolve the imaginary part into an actual value, we ignore at least the undefined term, if not the entire imaginary part, or we square the terms to remove the undefined term. This suggests we are not utilizing the full complex values for quantities or measurements. Distance is understood as a single-valued measurement (with appropriate units). Since we cannot represent a complex number as a single value, we are unable to provide a single value that could be used as a complex distance measure.

To gain a perspective on how to include the non-linear scale dimension into a single model of the universe, we could consider a simple model that collapses all three 'standard' dimensions onto a single dimension and then models scale along a separate axis. The collapsed dimension holds all linear dimensions, while the separate dimension is the non-linear dimension. We could model this using complex numbers and the complex plane as our simple model. This model might suggest that we are already making use of mathematics that differentiates our standard dimensions and measurements from a dimension that acts differently.

The author notes that the use of complex numbers in science has been increasing over at least the last century. The application of complex mathematical frameworks to a number of scientific areas provide support for this increased use:

- Complex Analysis: Many physical phenomena (especially in fields like quantum mechanics and electromagnetism) are most naturally represented in the complex plane, where analytic continuation, residues, and branch cuts play central roles.
- Wavelet and Fourier Analysis: Signal decomposition across scales often involves complex-valued transforms, where phase and scale intertwine.
- Renormalization: In statistical physics and quantum field theory, the renormalization group flow is often described not just by real-valued parameters, but by analytic

continuations into the complex scale plane, revealing critical phenomena and phase transitions.

- Fractals and Self-Similarity: Scaling laws in nature frequently exhibit complex exponents, as seen in the study of fractals and multifractal analysis.
- Logarithmic Spirals and Handedness: Many natural patterns, from galaxies to shells, are best described using complex logarithmic scaling, which encodes both magnitude (real scale) and rotation (imaginary scale).

What if we could find a means of fully representing a value for that pesky 'i'? This value certainly does not fall into the mathematical notations of today. So maybe mathematics needs to take a new step here. Maybe the more than 1000-year-old numerals we use today are not sufficient to represent 'modern' complex values. The ‘yi’ symbols used to define ‘imaginary’ values could be consolidated with the ‘real’ part of a complex number and reduced to a single value. This could simplify many equations made complicated due to 2-part complex values.

If we start to consider how to define a complex numeric system, we might extrapolate the pattern identified previously by adding reversing operations into the definition of a complex numeral. Maybe we need a fourth pair of reversing operations to fully represent complex numbers as single values without any unknown placeholder. A possibility would be integration and differentiation added into the definition of a complex numeric value. To represent negative square roots, we might need to define an undefined area of mathematics – that of negative bases. This might indicate a bit of theoretical work is required – maybe even a little inventing.

As Donald Knuth worked on more than 60 years ago (Knuth 1960), maybe we need to develop – to invent – numerals using negative bases, which can represent negative square roots. Euler’s great equation (e^(πi) + 1 = 0) might provide a clue to how to construct complex numerals, using ‘e’ as a base. When used for integration and differentiation, base ‘e’ allows for continuous integration or differentiation and does not ‘bottom out’ as typical bases do (e.g. Derivative of x^2 = 2x and derivative of 2x = c, bottoming out – while derivative of e^(2x) = 2e^(2x) and so the exponent does not decrease). A complex numeral might involve the positional placement of integrated and/or differentiated ‘digits’ in some similar way as exponential digits are used for decimal and positional base numerals. Directions for research might be Taylor or Laurant series.

The capability of incorporating integration and/or differentiation into numerals suggests integration and differentiation operations should become simplified. Consider that modeling upward in scale generally involves integration, suggesting such a numeral system could ‘take on’ the difficulties of the scale continuum.

This representational discovery or invention could open a new universe of possibilities for mathematics. It might also alter the interpretation of physical equations that ‘toss out’ the imaginary value for quantities and measurements, given that we can only use Real numerical values. Now we could have a value or measure that included the imaginary part. Now, a complex value could be handled in its complete form, possibly opening measurements not possible before (e.g., across scale). There would be complex measurements, not real measurements + imaginary placeholders – potentially identifying measurements we cannot make today.

Conclusion

As we move toward digitally modeling entire bodies in the universe, we will find the need for locating objects in scale, in addition to locating objects in three-dimensional space. This will require a four-dimensional scientific model of space, which will require some distance measure and units that cross non-linear scales. The ability to measure across non-linear scale becomes an imperative for a four-dimensional scale space model of nature. This leads to the need to advance the underlying means of representing numbers, so that such exponential distance measurements can be adequately quantified. Continuing the pattern of developing numeral systems to represent values for Integers, Rations, and Reals, the author recommends developing a numeral system that can adequately represent Complex numbers. As with the other numeral systems, this includes representing a complex value as a single value rather than the current method used today.

The mathematical conjecture is that complex values should be able to measure across scales. Supporting this assumption is the pattern suggesting integration and differentiation appears to be the next reversing operations to add to a numeral system, along with the use of integration and differentiation in multi-scale modeling today. In addition, the author notes that decimals use three reversing operations to represent the Real numbers, useful for three-dimensional work, and the next numeral system to represent Complex numbers would use four reversing operations to represent four-dimensional work.

It is very possible that such a numeral system may not be representable using traditional paper and pencil methods, requiring the use of computers. It is also possible that we need to shift to this new numeric system en masse across all areas of scientific fields that involve scale – moving away from strictly Real values represented by decimals (as was done prior to the current scientific explosion over the past five centuries).

It is not a huge step to consider systems beyond a complex numeral system - beyond where we do not quite see yet. So, we may still be in the early stages of understanding the extent of what mathematics can provide and science can utilize. Where mathematics needs to go could be well outside the 'standard model' of current mathematics (with only a Real line continuum) - and there might be tremendous dividends for science as well.

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