

Dimensions -- A Feynman-Style Treatment

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Abstract

Following Feynman's principle that a concept not explainable to a curious non-specialist is not yet fully understood, this essay rebuilds the concept of dimension from scratch. It moves from one-dimensional measurement through spatial geometry to abstract information-spaces, and argues that the explosion of infinity at any level of analysis is always a signal of missing dimension rather than of fundamental indeterminacy. The essay concludes with implications for ISL's treatment of constraint geometry.

Why Do We Need Dimensions?

And Are They Fundamental to Nature?

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A dimension is not a corridor in the universe. It is a direction the observer has learned to count.

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I. Let's Start With Something Embarrassingly Simple

Draw a dot on a piece of paper.

Now answer this: how many dimensions does that dot live in?

You'll say two. The paper is flat, it has length and width, obviously two dimensions.

But wait. The paper has thickness. So three dimensions, surely.

And the paper exists at a particular time. So four.

And if string theory is right, there are six or seven more curled up so small you can't see them from where you're standing. So ten or eleven.

Same dot. Same piece of paper. The number of dimensions is not a fixed property of the dot. It depends entirely on which distinctions you have the equipment -- and the need -- to make.

The dot didn't change. Your ruler did.

This is the thing about dimensions that nobody tells you when you're first learning physics. We treat dimensionality as if it's a feature of the universe, stamped in from the beginning, non-negotiable. Three spatial dimensions, one time dimension, done.

But look carefully at how dimensions actually work, and you find something different. Dimensions are addresses. They are the minimum number of numbers you need to locate

something. And the number you need depends on what you're trying to locate, at what scale, and with what instruments.

Change the scale. Change the number.

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II. What a Dimension Actually Is

Let me give you the honest definition before the fancy one.

A dimension is a direction along which things can differ. That's it. If two things can differ in exactly one way, you need one number to describe that difference. One dimension. If they can differ in two independent ways, you need two numbers. Two dimensions.

The fancy word for this is degrees of freedom. And that phrase already smuggles in the key insight: freedom. A degree of freedom is a way the system is free to vary. Take that freedom away -- constrain the system -- and the dimension disappears. Not because the universe shrank, but because the constraint removed the possibility of variation in that direction.

A bead on a wire lives in one dimension. Not because space is one-dimensional, but because the wire has removed the bead's freedom to move in any other direction.

This is the first important thing: dimensions are not intrinsic to the object. They are a description of the object's available freedoms, relative to whatever is constraining it and whatever measurement apparatus you're using.

The address system

Think of it this way. If you want to meet someone in a city, you need two numbers: a street and an avenue. Two dimensions. That's because cities are (roughly) flat. But if you want to meet someone in a building in a city, you need three numbers: street, avenue, floor. The building added a dimension -- not because the city changed, but because you now need to make a new distinction that was irrelevant before.

Physics is the same. At the scales of everyday life, three spatial dimensions plus one time dimension is the right address system. Everything you need to locate fits into four numbers. But at the scale of a proton, or at the scale of the very early universe, the address system may need more entries. More distinctions become necessary. More dimensions appear.

The dimensions didn't appear out of nowhere. They were always potentially there. But at your previous scale, you didn't need them, so you didn't count them.

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III. The Scale Ladder and Dimensions

Here is where it gets interesting.

In the ISL framework, we've established that infinity is a scale problem -- every time something

looks infinite, it turns out to be finite when examined from a larger scale, and a new horizon opens at the edge of that larger scale. The scale ladder describes this: each rung resolves one set of infinities and opens the next.

Dimensions follow exactly the same pattern.

At the scale of naked-eye experience

Three spatial dimensions. This is not arbitrary. It's the number of independent directions in which macroscopic objects can move relative to each other. At this scale, the address system needs exactly three entries for space. Time appears as a fourth, but a strange one -- you can move freely in space, but you only move forward in time. The asymmetry is real and demands explanation, but let's not get ahead of ourselves.

At the scale of electromagnetism

Maxwell's equations work in four dimensions. The unification of electricity and magnetism into electromagnetism by Maxwell in the 1860s was, among other things, a dimensional discovery: what looked like two separate phenomena in three-dimensional space turned out to be one phenomenon in four-dimensional spacetime. The fourth dimension wasn't added from outside. It was already there, invisible until you had the right ruler.

At the scale of general relativity

Einstein showed that spacetime is not a flat four-dimensional container but a curved four-dimensional geometry. Gravity is not a force -- it is the curvature of the spacetime address system itself. The dimensions are still four, but they are no longer independent. They bend around mass and energy. Dimensionality is now dynamic, not fixed.

At the scale of quantum field theory

Things start getting stranger. The path integral formulation of quantum mechanics requires you to sum over all possible paths -- effectively treating infinite-dimensional function space as the arena of physics. The three dimensions of space plus one of time is now an approximation, a slice through a much higher-dimensional space of possibilities. The dimensions you see depend on which observables you're looking at.

At the scale of string theory

Ten or eleven dimensions are required for internal consistency. The extra six or seven are compactified -- curled up so small that no current experiment can resolve them. They are not absent. They are simply at a scale below our current ruler's resolution. From inside our measurement scale, they look like zero dimensions -- they contribute nothing to the address system we can currently use. From inside a scale that could resolve them, they'd be as real as left and right.

The extra dimensions of string theory are not imaginary. They are below the resolution of our current scale. That is a very different thing.

This is the scale ladder applied to dimensionality. Each rung of the ladder uses a different number of dimensions. Not because the universe keeps changing, but because each rung is resolving a finer level of structure -- and finer structure requires more entries in the address system.

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IV. The Observer's Contribution

Now here is the part that connects to the Time as Scalar framework -- and it is the part most physics textbooks skip entirely.

When we say the universe has three spatial dimensions, we are not just making a statement about the universe. We are making a statement about the relationship between the universe and us, the observers asking the question.

The Time as Scalar framework established that time is not a constituent of nature but a measuring instrument observers apply to nature. The universe operates through causal structure and geometry -- none of which require a clock. The clock is the observer's contribution.

Dimensions are the spatial equivalent of this claim.

The universe does not have three dimensions the way it has mass or charge. It has a causal structure, a geometry, a set of fields. What has three dimensions is our current measurement apparatus -- our senses, our instruments, our theoretical frameworks. We impose the address system. We decide how many entries it needs. We choose the scale at which we're asking the question.

The formal statement

Let the universe's actual structure be some geometric object G -- a manifold, a causal set, a spin foam, whatever the final theory turns out to require. G has whatever structure it has, independently of any observer.

The dimensionality D that an observer measures is not a property of G alone. It is $D = \dim(\pi_a(G, s))$ -- the dimension of the observer's perception of G at scale s .

Change s -- move to a finer or coarser scale -- and D changes. The same underlying geometry G produces different dimensional descriptions at different scales. The dimensions are real. But they are relational: a property of the meeting between the geometry and the measurement scale, not of the geometry alone.

Asking 'how many dimensions does the universe have?' without specifying the measurement scale is like asking 'how long is the coastline?' without specifying the length of your ruler.

Mandelbrot's coastline problem, from the Infinity paper, appears again here. And it should. Because dimensions and infinity are the same kind of problem. Both look like fixed properties of the universe. Both turn out to be properties of the relationship between the universe and the observer measuring it.

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V. Are Dimensions Fundamental?

Now we can answer the question cleanly.

The answer has two parts, and both matter.

Part A: Dimensions are not fundamental in the way we usually mean

If by fundamental you mean: baked into the universe independently of any observer, fixed at all scales, the same number no matter how you look -- then no. Dimensions are not fundamental in that sense.

The number three is not engraved in the substrate of reality. It is the number of independent spatial directions that are resolvable at the scales of everyday human experience. Move to a different scale -- smaller, larger, or otherwise -- and that number changes. String theory needs more. Causal set theory suggests dimensionality is emergent from a discrete non-geometric substrate that has no dimensions at all until you zoom out far enough for the smooth geometry to appear.

Some approaches to quantum gravity -- loop quantum gravity, causal dynamical triangulations -- show that at very small scales, the effective dimensionality of spacetime drops toward two. Not because space is two-dimensional, but because the address system appropriate to that scale only needs two entries. The extra dimension is there in potential, but the structure at that scale doesn't require it.

Part B: Dimensions are real and necessary

But this doesn't mean dimensions are arbitrary or merely conventional. They are not.

At any given scale, the dimensionality that emerges is the correct answer for that scale. Three dimensions is not a human invention or a cultural choice. It is the genuine answer to the question: how many independent spatial directions exist at the scale of objects you can hold in your hand? The answer is three. That is a real fact about the geometry of the universe at that scale.

The point is not that dimensions are illusions. The point is that they are scale-dependent truths. True at the scale where they are measured. Potentially different at other scales. And the difference between scales is not a failure of description -- it is the scale ladder doing its job.

Dimensions are the universe's way of telling you how much address space you need at the scale you're currently measuring. The answer is always honest. It just isn't always the same.

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VI. What This Changes

If you take this seriously -- that dimensionality is a scale-dependent relational property, not a fixed intrinsic one -- several things shift.

The question 'why three dimensions?' gets reframed

The traditional question is: why does the universe have exactly three spatial dimensions? Why not two, or four, or seventeen?

This is a real question and people have tried to answer it. Some arguments involve the stability of orbits: in three spatial dimensions, stable planetary orbits are possible. In four, they are not. The anthropic argument says we observe three because we couldn't exist in a universe with a different number. These arguments have merit, but they smuggle in the assumption that three is the real number and the others are counterfactuals.

The reframing says: three is the real number at our scale. The question 'why three at our scale?' is a perfectly good scientific question. But it's not the same question as 'why three full stop?' -- because full stop doesn't apply. The universe doesn't have a dimensionality that is scale-independent. It has a geometry that produces different dimensional descriptions at different scales.

The question becomes: what is the geometry, and why does it produce three resolvable spatial dimensions at the scales where observers like us exist?

That's a harder and more honest question. And it's the right one.

The connection to time

Time as Scalar established that time is the observer's measuring instrument applied to the universe's causal structure. What we're now finding is that spatial dimensions have the same character: they are the observer's address system applied to the universe's geometry.

This is not a coincidence. Time and space are, in general relativity, components of the same object -- the spacetime metric. If one is relational (time as scalar), the other should be too. The argument extends naturally. The full four-dimensional spacetime address system is the observer's contribution. The underlying geometry is what the observer is measuring.

This doesn't make spacetime less real. It makes it more precisely understood: real structure, measured by a real instrument, producing real numbers -- where all three of those things (structure, instrument, number) are distinct and the confusion between them is the source of most of the muddle.

The Möbius observer and dimensional limits

There is one more connection worth making explicit.

The Möbius Observer paper established that every observer's self-knowledge is structurally incomplete. The architecture that enables self-reference is the same architecture that prevents complete self-description. The observer cannot see its own seeing.

This applies to dimensional measurement too. The observer's measurement apparatus -- the senses, instruments, and theoretical frameworks that determine what counts as a dimension -- is itself embedded in the dimensions it is measuring. You cannot step outside all dimensions to count them from a dimension-free vantage point. Every count of dimensions is made from inside some dimensional framework.

This means the question 'how many dimensions are there really?' may be structurally unanswerable from any finite observational position. Not because the answer doesn't exist, but because every act of answering it is performed by an observer whose architecture is itself dimensional -- and cannot fully see the dimensions it depends on.

We are, in this sense, exactly like the ant on the Möbius strip, trying to count the edges of the surface it is walking on.

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VII. The Scale Ladder, Applied

Let's run the scale ladder one more time, now with dimensions as the quantity being resolved.

Scale 1 -- Human experience: Three spatial dimensions, one time dimension. This resolves the question of how to locate everyday objects. New horizon: what are the dimensions of very small things, and of spacetime itself?

Scale 2 -- Relativistic physics: Four dimensions, unified and curved. Resolves the structure of spacetime and gravity. New horizon: what happens to dimensionality at quantum scales?

Scale 3 -- Quantum field theory: Effective dimensionality becomes scale-dependent. Renormalization group methods show that what counts as a dimension depends on the energy scale of the measurement. New horizon: is there a smallest scale at which geometry breaks down?

Scale 4 -- Planck scale physics: Dimensionality approaches two (some models) or zero (causal sets). Smooth geometry may be emergent from a discrete non-dimensional substrate. New horizon: what is the geometry before geometry?

Scale 5 -- ????: The next framework resolves what generates geometry in the first place. We don't have this scale yet. From inside our current framework, this question looks infinite -- unresolvable, beyond our reach.

Each step in this ladder is not a discovery that the universe has a different number of dimensions. It is a discovery that the relationship between the universe and the observer at that scale requires a different address system. The dimensions are properties of that relationship. When the relationship changes -- when the scale changes -- the dimensions change with it.

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VIII. Summary

Here is what we can say, and what we cannot yet say.

We can say: dimensions are scale-dependent. The number of dimensions an observer measures is not a fixed intrinsic property of the universe. It is the number of independent entries needed in the address system appropriate to the observer's current measurement scale. Change the scale, and the number can change.

We can say: dimensions are real. They are not arbitrary or conventional. At any given scale, the dimensional description is the honest answer to the question being asked at that scale. Three is the right answer for everyday space. More may be the right answer for subatomic physics. Fewer may be the right answer at the Planck scale. All of these are correct, at their respective scales.

We can say: dimensions are relational. They are not properties of the universe alone, or of the observer alone. They are properties of the meeting between the two -- the universe's geometry measured by an observer with a particular instrument at a particular scale. Remove the observer, and you still have the geometry. But you don't have a dimension count.

We cannot yet say: what the underlying structure is that produces dimensional descriptions at different scales. This is the open question at the frontier of quantum gravity. Causal set theory, loop quantum gravity, string theory, and several others are competing answers. None is settled. The scale ladder has a rung here that hasn't been built yet.

We need dimensions because we need to locate things. We use the minimum number the current scale requires. Nature provides the geometry. We provide the address system. The two are not the same thing -- and keeping them distinct is where the real understanding begins.

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