General Motion

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In this paper I introduce a framework of general motion for physics that unifies continuum mechanics, discrete mechanics and relativity. Using the language bias of this framework, I ground the truth of a broad notion of physics as the path semantics of idempotent functions.

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1. Introduction

When Newton wrote Principia, he was trained in mathematics in a particular way that is evident from his papers, using reasoning based on drawings and geometry. If you read Einstein’s papers, then you will see a different style of mathematics, more based on equations and thought experiments. Open up a paper by Feynman and you will see yet another style.

The changing style of mathematics in physics over time leads to a question: Can we understand physics in a broad sense, that is not tied up to a particular style of math? I think the answer is no. However, if we are willing to accept some language bias to get an intuition for physics in a broad sense, then I believe the answer is yes.

Path Semantics is my project to make mathematics as whole, including standard mathematics, easier to understand by presenting it as a study of functions, so students can progressively expand and generalize functions from deterministic and finite, all the way to quantum functions. This field is separated into foundational, standard and esoteric/non-standard path semantics. Beyond Path Semantics, there is a field called Avatar Extensions, that deals with abstract generalizations in math. In the big picture, there is a LOGI-circle (Logical, Outside, Global, Inside) that creates a map. Using the map, students can understand how different areas of Path Semantics interact.

A traditional way of viewing mathematics, is by using a single language e.g. built on Set Theory or Category Theory. In Path Semantics, students are taught to view mathematics from different perspectives using several languages and how to build their own and using theorem proving for good language design. In the end, people using Path Semantics need to program computers and to support this activity it is important to have a solid theoretical understanding of functions, not seen through a single lens, but as a diverse family of languages used for different purposes. The most important concept in Path Semantics is that of a normal path, that allows a person to reason using math about some function in another language than the function used for reasoning. The idea is to build tools and prove properties about the tools, building bridges from one field to another, instead of using a single language that might be difficult to optimize and specialize for a purpose.

Path Semantics goes very well with physics as a field and standard matematical notation. This is because Path Semantics helps particularly in understanding and grounding concepts in a unified way that can be easier turned into computer programs, but also to motivate design of mathematical languages for reasoning that might not be intended for executing instructions. Path Semantics is formal enough to assist a programmer, but also high level enough to help understanding theory. This is why Path Semantics is often used to ground truth of various mathematical languages, since the result can be translated to other languages for practical reasons and to other specialized fields.

With other words, Path Semantics is a modern mathematical framework for modern problem solving, that is not depending on particular mathematical languages, e.g. geometry or equations, that are popular in a particular historical period for solving specific problems. Through the lens of Path Semantics, we can look at existing ideas and see if there is a way to make them more applicable with modern tools and easier to understand for a wide target audience of experts in specialized disciplines. The goal is to make it easier for people to see how math can be useful for their field.
In physics, the biggest problem for people is to learn how to think through the languages of continuum and discrete mechanics. In continuum mechanics, there are infinite particles or physical objects. This might seem a bit mysterious, because the real world is made of finite physical objects. However, using continuum mechanics, one can solve practical problems without knowing the exact state of each individual physical object. In discrete mechanics, there are finite particles or physical objects. This is might seem intuitive at first, but upon closer philosophical reflection, one realizes that what one calls a physical object is merely an abstraction, a language design, instead of something that accurately describes reality. For example, in quantum physics, particles have both discrete properties and continuous properties. Neither continuum mechanics or discrete mechanics on their own are sufficient to understand modern physics. So, it becomes a problem for people that the languages of physics are confusing, not illustrating or presenting clearly what physics is about.

Using Path Semantics, one can solve this problem, by essentially not trying to pretend that physics is about reality in general, but through the perspective of a particular class of functions that provide intuition about general motion. In the end, physics can only measure and reason about things that move. So, one uses a particular class of functions to filter out anything that distracts attention, that does not focus on motion, in order to better see what physics actually is about. By paying attention to the perspective of physics through that very narrow lens, it can help people to understand physics as a whole, without depending on a particular perspective of continuity or discreteness.

2. Definition of general motion

A general motion `f` is an idempotent binary operator over some physical state:

$f : \text{state} \times \text{state} \to \text{state}$ binary operator over physical state

$f(x, x) = x$ for all `x` idempotency

The first argument is called “initial state” and the second argument “observer state”. Idempotency means that when the initial state equals observer state, the motion produces the initial state.

Intuitively, when observing yourself, you find yourself in the same state as you are observing in. This is the condition where the observer and the state being observed are also the state that moves.

Space and time in our universe (in a classical perspective) are functions on the state:

$\text{time} : \text{state} \to \mathbb{R}$

$$space : state \to \mathbb{R}^3$$

A state is a physical point in space-time when:

$$state \quad \Leftrightarrow \quad time \times space$$

With other words, when measuring a time of a state `x : [time] t` and position `x : [space] s`, if one can reconstruct the state `x` from `t` and `s`, then the state is a physical point in space-time.
For example, when using Navier-Stokes equations with trace particles modeling some fluid.

3. Time-locality vs cutting-edge research in physics

In most physical theories, we do not need to depend on the position of an observer. This property is called "time-local". A general motion `f` is time-local when there exists a normal path:

$$f[id \times time \to id]$$

When interpreting time-locality in reality, we are measuring something very close to the object in an approximate flat space-time, such that space-time geometry does not curve beyond speed of light. If the initial state is inside the event horizon of a black hole and the observer state is outside, space-time curves beyond speed of light, so much that the time of the observer must be translated along the bending geometry of the black hole into a coordinate so close to the initial state that one can treat space-time as approximately flat. This transformation depends on the position of the observer. Using the time of the observer alone is not sufficient information to describe the motion. In reality, there is no actual logical contradiction between the observer and the initial state, it is just that common intuition for motion is simply a reduced version of general motion that is time-local.

From the uncertainty principle in quantum mechanics we know that the position and momentum of a state can not be measured with 100% accuracy. Likewise, the same holds for time and energy. So, when you are dealing with systems that are not time-local, it is understandable that the physics becomes more complex and the motion can exist in super-position. This simply follows from the fact that when there is no unique way of getting the position and time from an observer state, there is no unique way of getting the initial state either, such that the motion is not well defined by idempotency using repeated experiments. If there is no agreement on what `x` is, then idempotency only holds in relation to a particular perspective of `x` and not for all perspectives of `x`. The definition of a general motion is such that it normalizes to a singleverse perspective of physics.

In principle, there is no logical contradiction in having a multiverse, it just that general motion is not unique in the multiverse, a property that follows from idempotency and disagreements about `x`. This should not be confused with reality, because it is a property of the language. Yet, when we measure how things move in the real world, we find that this property of language also is reflected in the experiments, something we call "quantum behavior". With other words, by coming up with more precise ways to describe disagreements about `x` according the uncertainty principle, we also got more precise ways to describe reality with the uncertainty built-in. The uncertainty comes from anchoring language according to general motion. Without this bias, we would not be able to define what the uncertainty was about. So, it is not a logical contradiction. Idempotency and quantum behavior mutually support each other in language. Besides this fact, it is remarkable that this property of language also turned out to be measurable in reality.

So far, I have talked about the property of time-locality. Time-locality makes it easier to reason about physical systems because we do not have to be concerned about the position of observers. There is common misconception that quantum behavior only appears when a system is not time-local. This is not true. Time-locality only makes it harder to understand quantum behavior because it is so close to common intuition of physics, so by relaxing the language a bit to include systems without time-locality, one can easier understand how quantum behavior is possible. This is because humans have intuition of disagreements due to different perspectives in space, but struggle visualizing disagreements due to different perspectives in time. However, quantum behavior is possible because of idempotency, when observers do not agree with each other according to their own perspective and biases that are associated with time-locality, but not directly related to it.

Most people interpret the uncertainty principle as something that can not be known, which leads to all sorts of misconceptions about physics. Two observers can disagree about measurements, which is the uncertainty principle. In fact, the uncertainty principle implies that if two observers measure physical quantities with 100% certainty that violate the principle, the two observers will not be able to communicate with each other. It is not due to lacking epistemic certainty. The uncertainty principle is not about subjective beliefs about some unknown state, but can be used to predict something about the multiverse. It puts a constraint on the language of the multiverse. When interpreted from the perspective of a single observer, the principle translates into uncertainty. However, from a multiverse perspective, one might call it “the discommunication principle”.

One challenge in modern physics is to figure out how information is preserved in a singleverse. It follows from the possibility that observers can disagree, that when they according to the uncertainty principle from a multiverse perspective can no longer communicate with each other, that it is natural to ask the question: Is information preserved from a singleverse perspective?

This question has brought physicists on a long journey of discoveries where they concluded that the theories of General Relativity and Quantum Field Theory contradict each other logically. These two theories are not compatible. Therefore, to have a theory of everything, it must be able to explain what happens at quantum levels close to the event horizon of a black hole, which can neither be predicted by General Relativity or Quantum Field Theory. Either, information might get destroyed at the event horizon from a singleverse perspective, or it might be preserved somehow, e.g. using the holographic principle. What physicists are looking for, is some principle that can be tested with experiments that constrain the language of a theory of everything. Today, we do not know how to test any of the suggested principles, but one can perform theoretical calculations to check that a theory is consistent, which is necessary to qualify as a theory of everything.

The problem lies in defining precisely what it means to have information from a singleverse perspective and how it transforms over time, either in a way that it is preserved, or in a way that it is lost. Any person who manages to solve this problem and comes up with a way to test it using an experiment, will win a Nobel prize. However, it is an immense difficult problem because we can have a clear intuition about general motion, yet at the same time be very vague in language about what information means in that context. From a multiverse perspective, the discommunication principle makes it intuitive that some information might be lost from a singleverse perspective, because, propositionally, the relation “A and B can communicate” feels like a bit of information. If this proposition no longer holds under general motion, then what kind of information is it translated into, or what happens at the moment when it vanishes from a particular perspective? It is like looking for a needle in a haystack without necessarily having a good idea of how the needle looks like. Yet, people have come up with very good approaches to attack this problem. This is an effort that continues and hopefully one day we will be able to test it with a scientific experiment.

Therefore, the cutting edge of theoretical physics is about working on problems related to time-locality, even though it is not strictly outside the set of general motions that are time-local. It is just easier to visualize a thought experiment by relaxing time-locality.

4. Is there something like an “ordinary” physics?

Now, the question is: How can we use general motion to define physics in an ordinary sense?

For example, consider a phyiscal object at rest. In a fluid, one can define rest as the velocity field being zero everywhere. For a particle, one can define rest as the velocity being zero. Intuitively, one understands that here is some kind of connection between the two, but it is not easy to see due to the conceptual difference between continuum and discrete mechanics. To come up with a definition that unifies the two might seem difficult at first.

It turns out that defining general motion at rest is a surprisingly easy problem to solve.

A general motion `f` is at rest, when:

$$f[\text{space} \times \text{unit} \rightarrow \text{space}] <=> \text{id}$$

The `unit` is a generic function that has type `T → ()` where `T` is a generic argument and is used to erase information in a normal path. In this case, one gets the type `state → ()`. The state that is erased is the observer state. This means, by knowing the position of the initial state, the motion has the same position, which intuitively translates into the idea that the physical object is at rest.

Now, can you prove that all general motions at rest are time-local?

This problem seems easy to solve at first, because when we focus on the position of a general motion at rest, it does not depend on any property about the observer state. If one only has time from the observer, which is not needed for motion at rest, but should it not follow that the motion is time-local?

When trying to set up the proof, one immediately sees a problem:

$$\begin{array}{ll} \because & f[\text{space} \times \text{unit} \rightarrow \text{space}] <=> \text{id} \\ & \ldots \\ \therefore & f[\text{id} \times \text{time} \rightarrow \text{id}] \end{array}$$

A general motion at rest uses a normal path with `space` instead of `id`, which does not tell us everything about the state, so it is not clear how to restore the state properly.

When encountering a problem like this, it is easy to give up, because it seems so trivial thing to prove at first, yet when it looks impossible to solve, what is the benefit of solving it? Why not go work on the cutting-edge research that relaxes time-locality instead? The problem is that humans are often biased to work on stuff that looks impressive, but things that look impressive might also be high risk of not making any actual contribution to science. The most valuable contributions in science are discoveries that help people to understand simple things, not impressive things. Therefore, daring to solve simple-looking problems which we do not have any general solution, can lead to breakthroughs and for new people to make a name for themselves.

First, we need a way to restore the state from position. However, if we simply restore the state directly from position, then there can be no movement in time. The very idea of some physical object at rest seems to include some notion of time that varies while holding the position constant. So, where is the time? If you look carefully at the definition of a general motion at rest, then you will notice that it does not mention time at all!

This is my point: Just because a simple problem is not solvable, does not imply that there are no valuable insights to learn by thinking about it a little. If you rush through life, then you will miss out on these moments when you learn something new, even though it is not something to brag about, but it makes your understanding more solid and makes stuff less confusing later on.

When you read papers about physics where the author says “assume the object is at rest”, you now understand that the author is referring to a kind of state of the object which might be timeless. In one sense, the object might be eternal, but in another sense, it can also just exist in a single moment without having a definition outside that moment. If you broaden the latter perspective, then you can think about particles popping in and out of existence, but their total contribution looks like nothing happened. The vacuum state can be at rest in one sense, but also chaotic from another perspective.

Now, if you tie this back to the cutting-edge research where physicists are thinking about preservation of information from a singleverse perspective when time-locality is relaxed, you can think about the information of a vacuum state as zero close to the event horizon of a black hole. There is some kind of chaotic fluctuation, but if the total contributions of these fluctuations remain zero, then the information is preserved. However, if the black hole radiates heat over time by one of two coupled particles falling inside the black hole, then some more complex explanation is needed that has something to do with the vacuum state. Stephen Hawking suggested that information zero in this sense is kind of like when you have a flat piece of paper, but when you curl it up without tearing it, you add some information in some places and removing it in others.
In quantum mechanics, you can have complex amplitudes, where some amplitudes cancel each other out due to pointing in opposite directions, even thought this “direction” is not something we can access directly in reality. It is a relative term between contributions to some event happening.

When you view this from the multiverse perspective of the discommunication principle, it is easy to think of the observers who can no longer communicate as kind of like wrinkles on a crumbled piece of paper, except they are located at the opposite sides. When one side goes up, the other side must go down. So, in this sense, the fact that they can no longer communicate is not contradicting preservation of information. Instead, it supports the argument of preserving information! It is possible that the universe started as a fluctuation in a chaotic vacuum state and everything that points “up” in time has a corresponding “down” seen from another parallel universe.

This raises the question: Does information preserved from a singleverse perspective mean that one has to include the coupled upside-down perspective?

Now, you see why this gets complicated, because while something might seem to disappear from existence, it can have consequences in the future just because the thing that vanished still exist “somewhere”, although saying precisely where might be difficult, and it is mathematically linked to things that still exist. This kind of pushes the boundary of what we mean by a singleverse. Actually, the more one thinks about the singleverse, the less it makes sense and one ends up back with a multiverse perspective, if one takes what happens in a singleverse far enough in time.

In cyclic cosmology, one treats the total information of the entire universe as zero and imagines that if far enough time has elapsed, which can even be infinity, then relative to that seemingly undefineable moment, if one can assume it, then there is a possibility for everything to start over. This means, in the new era, when the universe has started over, nobody can get any information from what happened before a certain point in time. No less than there is a “north” of the north pole.

Or, like a flat piece of paper is its own thing, the universe might have a “flavour” that remains constant over the total contributions of all moments in time. Or, you could have alternating flavours. Or, you can have nonperiod repetitions, like an Einstein tile, such that no era is located in relation to all other eras in the exact same way. Either way, it is not certain we can tell the difference from within the universe.

When I started looking closer at what it means for a general motion to be at rest, I observed that time was not relevant for the definition at all. By tying it to cutting-edge research, I ended up with complex perspectives of time where time itself ceases to be a direct meaningful construct, but can bring some insights into cosmology. This shows how flexible general motion is as a language for physics. A lot of creativity goes into producing different interpretations of seemingly simple ideas.

5. Newtonian physics

General motion gives a very different perspective of physics than the narrow language used by Newton to think about it. Newton lived in a time where his ideas were cutting-edge and breakthroughs in system thinking. Today this is just one of many perspectives in physics. General motion leans toward all branches of physics, instead of a particular one, because one can use more imagination more while keeping the formal language to a minimum.

This leads to the question: What kind of motion is Newton thinking about?

In general motion, one can easily think about continuity, discrete or relativity in one go. However, Newton focused on motion without relativity. Intuitively, this motion is time-local, because it does not depend on the observer position. However, time-locality does not exclude relativity, because the motion can return a state that displaces time relative to the observer time.
Non-relativistic general motion `f` has the property:

$$f(x)[\text{time} \rightarrow \text{time}] \Leftrightarrow \text{id} \qquad \text{for all `x`}$$

If you are lazy, then you can use symmetric notation:

$$f(x)[\text{time}] \Leftrightarrow \text{id} \qquad \text{for all `x`}$$

This means, the time from the observer state is the same as the time in the motion.
Since there is no displacement of time, the motion is non-relativistic.

For example, although general motion seems simple at first, when you try to create an algorithm to simulate a fluid, it can be very difficult to visualize how infinite particles with a non-uniform velocity field moves in space-time. You have to think carefully about how to get the math right.

In general, the problem with relativistic motion is that it is more difficult for humans to visualize and hence solving problems gets harder, because understanding something often requires being able to imagine or observe something in the first place.

It is not like Newton was stupid. On the contrary, using a universal time makes his theory more applicable to the problems of his day. However, once people get used to that way of reasoning, it can be difficult to go back to general motion. I think this is one of the reasons why general motion is needed, simply to argue in a straight forward way what physics is about in general, including the fields that depends on relativistic or quantum behavior of systems.

When dealing with physical points, one can use a normal path non-relativistic general motion `f`:

$$f[\text{id} \times \text{time} \rightarrow \text{space}]$$

This works because the position and time can restore the state. Since the time of the observer is the same as the time in the motion, one only needs to calculate the position.

You can also use the same normal path for some non-physical points, if the state can be restored from the initial state, plus the time and position in the motion. For example, when a 2D ball is rolling with 100% friction against some surface without slipping, it is possible to approximate the orientation of the ball simply from the position of the initial state and the motion position, ignoring the details about the surface it is rolling against, as long the distance is short and assuming that the ball rolls along some surface in a straight line.

There is a huge set of problems that can be solved simply by calculating a position over time. It is also a good approximation under many circumstances, for example, when a horse travels from one place to another and the observer does not look at the horse continuously, you can just figure out some natural way of spawning the horse at the desired poistion, perhaps out of sight, without the user noticing anything strange.

6. Psychology and ethics as part of a broader notion of physics

In many cases, you want to reduce general motion to the simplest possible form needed to solve some problem. However, there are also cases where you do not actually need to predict anything in particular, such as a position, but instead reason more generally. This is the case when using general motion to reason about psychology. A patient might be thought of as being in some initial state and the therapist as being some observer. The fact that both the patient and the therapist share a similar type of state, helps to understand how a therapist might identify emotions and thoughts in the patient under observation. In many such cases, there is no need for accurate measurements.
It is unusual for most people to think about psychology as a part of physics. Yet, general motion does not discriminating against psychology in particular, which would be very strange when considering how many other fields it covers. Psychology is also part of the universe and is a physical process. To explain how general motion can be used in psychology, it is a good idea to draw ideas from Avatar Extensions instead of normal paths in Path Semantics. The symmetry between the patient and the therapist can be exploited in the abstract generalizations that are studied under Avatar Extensions, often without being able to pinpoint the exact physical states or making accurate measurements. However, it can still involve physical concepts such as space and time, e.g. by making appointments for a meeting and giving the patient instructions in advance to help speed up recovery. However, a particular space and time is not usually relevant for therapy and plans can change if they collide. Avatar Extensions deal with concepts that are relevant for psychology, such as whether different parts of the brain in the patient are good at balancing each other.

Another field where general motion is relevant is ethics. In ethics, the position of the observer is often relevant, for example, whether some event to be judged ethically takes place close to the observer vs a neighbor country vs a parallel universe. In general, some events are more ethically relevant from some people than others and this varies greatly from one person to another. In ethics, it is important to recognize the diversity in ethical judgements, but also the struggle to improve society overall across those diverse judgements. It is a field where motion should usually not be considered time-local, because this plays down the important part of how practical ethics operate in the real world as opposed to idealized ethical thought experiments. Thought experiments can help, but the overall problem is that people make ethical judgement from a biased perspective and with partial information, occasionally with questionable morality. The complexity of ethics is both challenging, but also something that could be improved by viewing physics through a broader lens.

7. Linear vs harmonic motion

When we solve non-linear equations using numerical simulation, we treat the physical system as reducible to linear general motion for short time intervals and distances in space. This is the most common physical language, relying on accurate theories for initial and observer state.

Next to linear general motion, harmonic functions are common in physics, that can give another perspective. However, the translation from linear general motion into harmonic functions and back is lossy. We have to ground truth on one side. So, general motion is language biased.

8. Defining physics

If you accept that motion is grounded in general motion,
then a broad notion of physics can be defined as:

physics = path semantics of idempotent functions

This is the bridge from Path Semantics into physics.