# Perfect Physical Predictors

by Sven Nilsen, 2017

*One important idea in physics is that the same physical systems can be described when changing coordinate and units of measurement. Here I demonstrate, using the concept of perfect physical predictors, that the semantics of such transformations is derivable from the existence of functions using path semantical notation.*

Assume you have a particle moving with a constant velocity in a single dimension. A such system can be described as a function of the initial position, the initial velocity and time:

f(pos, vel, time) = pos + vel * time

Now, instead of using this function directly, we will transform the arguments:

to_new_pos(pos) = pos + 10

to_new_vel(vel) = vel – 2

to_new_time(time) = time * 4

This describes the system `f` in a different reference using a different unit of time. In path semantics, one can describe this as an asymmetric path:

f[to_new_pos × to_new_vel × to_new_time → id]

The existence of a such path is called a “perfect physical predictor”, because it predicts the output of `f` from the data you get after transforming the input. Path semantical notation guarantees that the interpretation of what this function does is sound and perfectly accurate. The predictor can be used instead of computing with `f`.

The deeper idea behind path semantics also tells us that the ability to make such physical predictions is not arbitrary. All of path semantics has grounded meaning in functions. If you accept the concept of functions, you also have to accept that the truth value of a perfect physical predictor is either 0% or 100%. Either the path exists, or it does not. Any other probability assigned to a perfect physical predictor is subjective, e.g. a Bayesian belief that the function `f` is an accurate description of the physical system.

Each transformed input has an inverse, so a path must exist since the structure of the input is preserved. In our example, the path is:

h(pos, vel, time) = (pos – 10) + (vel + 2) * (time / 4)

The function `h` has the property:

h(to_new_pos(p), to_new_vel(v), to_new_time(t)) = f(p, v, t)

One can also write this:

$$h(p, v, t) = f(to\_new\_pos^{-1}(p), to\_new\_vel^{-1}(v), to\_new\_time^{-1}(t))$$

While this is a very simple case, it demonstrates the idea for all cases in general, where you can pick any transformation you like:

$$f[g_0 \times g_1 \times g_2 \rightarrow id]$$

Notice that, counter-intuitively to common sense, once you have written down the physical system as a function, then all possible perfect predictions are determined only by existence of functions in path semantical space. It does not depend on whether the universe behaves in a quantum mechanical way or in a classical way. It does not depend on what you believe about the universe, at all. The laws for what is possible to predict perfectly can be derived mathematically using path semantics.

One can use this property to prove when an observer is able to predict the behavior of a physical system. If a physical system is measurable and describable relative to some reference frame, then it is also measurable and describable in the reference frame of the observer if and only if the path of the function exists, using transformations corresponding to the change of reference frame.

For example, if Bob use cartesian coordinates and Alice use polar coordinates, and they move at constant velocity relative to each other, it is possible for Alice to describe the same physical system that Bob see because there is a way to convert back and forth between cartesian coordinates and polar coordinates.

If Alice and Bob use the law of special relativity, and Bob enters the horizon of a black hole while Alice stays outside, the change of reference frame is greater than the speed of light and the calculations Alice performs about what Bob see does not make sense. There exist no function that predicts the output given the transformation. Using the law of special relativity, is not sufficient to make sense of the world through Bob's eyes when you are outside the black hole. You need the law of general relativity or perhaps a law of quantum gravity to make sense of the world in this case.

As humans we often feel the world ought to always make sense in a such way that all observers can agree on everything, and this way should correspond to what we feel is intuitively true about the world from everyday experience. However, this is simply not the case, because once you have written down a physical system as a function, it is also possible to predict the *absence of any predictions* by using path semantics. When this happens, you have no other option but to look for a better theory.

Here is another example: Assume you have a particle moving with a constant velocity and then changes suddenly to another velocity at time $t_x$. Why is not `f` a predictor of this system?

The reason is that `f` only predicts systems that has a constant velocity. If a particle moves at constant velocity up to time $t_x$, then `f` can predict the behavior up to that point in time, but no further. If a particle moves at constant velocity after time $t_x$, then `f` can predict the behavior after that point in time, but not before. It can predict the behavior before and after, but not for any range of time containing time $t_x$.

This fact is precisely so because if you restrict the system, let's call it `$f_x$`, to two partial functions, you can replace it with `f`, but only by transforming the input in one case:

$$f_x(p, v, t) = f(p, v, t) \qquad t < t_x$$

$$f_x(p, v, t) = f(g_p(p), g_v(v), t) \qquad t > t_x$$

Again, this shows that predicting the output of a function is only possible when there exists a function that you can use instead. The only difference between predicting a function using another function and predicting the outcome of some experiment performed in the world, is that the function in the world is unknown.

Assuming the world is unpredictable means assuming the non-existence of a function that predicts the world. Actually, this is the case in quantum mechanics when certain classical properties are not well defined for the same instant of time. There are no perfect physical predictors for such cases.