Proposed solution for Zeno's paradox and a proposed physical model for wave-matter duality.

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This article is an elaborate translation for an appendix we wrote in the Arabic book: "Quantum Physics and the Existence of God" (الفيزياء الكمية ووجود الخالق), in which we have proposed a philosophical solution for Zeno's paradox. This solution does not necessarily derive from Quantum Physics, but it is in line with it.

"Zeno of Elea" was a Greek philosopher at the fifth century BC. The following paradox is attributed to him:

> Suppose we moved an object from point a to b. But before this object has reached b it passed through point m1 which is at the middle distance between a and b. But before the object has reached m1 it passed through point m2 which is at the middle distance between a and m1. But before the object has reached m2 it passed through m3 at the middle distance between a and m2. And so forth.
>
> Knowing that there are infinite middle points between a and b, logic dictates that the object cannot reach point b, but it did reach that point,, and this is Zeno's paradox.

There are many proposed solutions for this paradox (Google: Zeno's paradox solutions), and we will propose here another solution that might be more satisfactory for this paradox.

Let us first provide the framework for this discussion:

> **1#** The Greek have concluded that "matter" consists of elementary particles that they called "Atoms", which we will call here: "Greek Atoms". Their logical analysis was as follows:
>
> Let us take an object. This object can be divided into smaller parts, and each part can be divided into smaller parts, and each part can be divided into smaller parts. And so forth.
>
> But this cannot continue to infinity otherwise all mater can be divided into nothing. Therefore, there needs to be a particle that cannot be divided into more smaller parts, and this is the "Greek Atom".
>
> Now ... This is <u>not a logical conclusion</u>, but it is a <u>necessary closure</u> for the above logical analysis.
>
> This conclusion is now supported by quantum physics with a slight adjustment: there are many types of "Greek Atoms" (which are called "elementary particles") which cannot be divided into smaller parts. Electrons are among these elementary particles.

2# At the start of the 20th century "Max Plank" has discovered that Energy is a quantized variable. This means that Energy does not move smoothly from a level to another level, but it makes multiple jumps from a level to another level. Each jump represents an addition (or subtraction) of a quantity of energy (which is called Quanta) that cannot be divided into smaller values. This means that Energy can either be zero or one Quanta or integer multiple of Quanta.

3# In 1913, "Niels Bohr" presented his model for the atom's internal structure. In this model, Electrons don't ascend (or descend) smoothly from one orbit to another, but they jump from one orbit to the other.

The issue we want to raise here is that the concept of jumping from a level to another level is a familiar concept in Quantum Physics. This concept will be used in our proposed solution for Zeno's paradox:

Let a particle be moving from point a to b, then this movement is not carried smoothly, but within multiple jumps from a to b. The minimum jump is a "Quanta of distance" that cannot be divided into smaller parts. Therefore, there is a length of distance that represent the smallest distance (the Quanta of distance) and particles cannot move shorter than that. Therefore, particles can either be standing still, move one Quanta, or move integer multiple of Quanta.

Returning back to Zeno's paradox, if we start to slice the distance from a to b with middle points: m1 between a and b, m2 between a and m1, m3 between a and m2, etc., then we will reach to Mn (which is a middle point after "n" slices) with the distance between a and Mn is less than the length of Quanta. There the slicing stops; because objects don't jump shorter length of Quanta.

Therefore, "n" is the finite count of middle points between "a" and "b", which the particle needs to pass over before reaching point b.

But there is a serious consequence for this proposal: In order for a particle to move multiple jumps from a to b, then it needs to disappear at its location and appear after a distance of Quanta. Then (after a short time) disappear again and appear after another distance of Quanta, and so forth until it reaches point b.

This is not easy to comprehend, but we argue that this conclusion is a necessary closure for Zeno's logical argument.

We would like to stress here that the "disappearing & appearing" of particles does not necessary means that Objects will "disappear & appear". This issue will be discussed later.

Furthermore, the quantization of movement can be supported by analyzing the following equations:

Let an object be at rest at a distance from earth and then let it fall freely. Therefore, the following equations are valid:

$v = a.t$ ..... Equation 1
$d = (0.5)\ a.t^2$ ..... Equation 2
$E = (0.5)m.v^2$ ..... Equation 3

Where:

- v: The velocity.
- d: The distance from the rest location.
- t: Time.
- m: The mass of the object.
- a: Constant representing the acceleration caused by the gravitational force.
- E: The kinetic energy.

As the object falls down to Earth, then its speed (v) and kinetic energy (E) increases.

But E is quantized value. Therefore, it is reasonable to conclude that v (velocity) is also quantized (as can be seen from Equation 3). This means Velocity doesn't change smoothly from a value to another value, but it would make multiple jumps from a value to another value. Each of these jumps is a "Quanta of speed" (that is the minimum speed). Therefore, the velocity (speed) of the object will be either zero, one Quanta, or integer multiple of Quanta.

> **[Notice** that if velocity was not quantized and it does change smoothly from a value to another value then will have here Zeno's paradox but with velocity rather than distance].

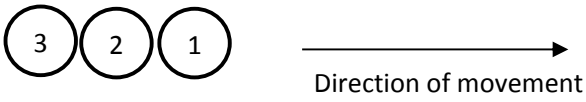
But if Velocity is quantized then time is also quantized (as per equation 1). Therefore, time does not change smoothly from value to another value, but it makes multiple jumps from a value to another value. Each of these jumps is a "Quanta of time" (that is the minimum time duration) and time cannot have a fraction part of it.

But if time is quantized then distance is also quantized (as per equation 2). Therefore, Objects cannot move smoothly from their location to another location, but they make multiple jumps from their location to another location.

Now ... the quantization of "energy, velocity and time" is simple; there is a variable (let it be energy) and there is One Quanta (or integer multiple of Quanta) added to it or subtracted from it. But the quantization of distance is different, it requires from particles to jump from one point to another for a distance that cannot be shorter than one Quanta. The only possible explanation (yet) for that jump is to say that particles "disappear & appear" from one point to another.

Now let us discuss the movement of Objects vs particles:

For the sake of this argument let us assume we have an object that consists of 3 particles in a row as in the following figure:



The movement of each particle will be through multiple jumps forward. But the movement of this object can have the following two possibilities:

- Either all particles of this object jump together. Therefore, this object will "disappear & appear" in forward jumps, multiple times.
- Or particle 1 will jump first, then followed by particle 2, then particle 3. In this possibility, particles will "disappear & appear", but the object will not. Instead the object will "stretch and shrink" multiple times in the direction of movement.

It is obvious that if "movement" is quantized then the second possibility is more sensible, but the first possibility is still valid.

The possible mechanism of which motion can be quantized is yet incomprehensible. Even the mechanism of which energy can be quantized is yet unknown. However, the motion that is created in films and computer games can be an interesting philosophical analogy that might be useful to explore:

- The motion in films is just an illusion; they are pictures that flip in high rates (about 24 frames per second) which give us the sense of "motion" in films.

- The same is for computer games: suppose we have a white computer screen with a red box, and we want to write a program to move this box smoothly to another location. What we will do?

  We will write a program that changes the color of the box to white (the color of the background), then it will locate a square space (equal to the size of the box) at a small distance from the original box and change its color to red. Then after a very short time, the program will change the color of that box to white again and continue the process. This will give us the illusion that the red box has moved smoothly from its location to another location.

It is very clear that motions in films and computer games are "quantized". But how is it done? what are the processes that make it work?

The computer screen consists of compact points which can be configured to have any color. Therefore, we can choose the color of the whole screen to be white, and then we change the color of any area in it.

Therefore, the appeared motion of the red box was due to the continuous change of configurations. This means that the configuration of each point has changed over time, which provided us with the illusion of a moving red box in an empty screen.

The same can be said for Films (and old animation movies) where there are many pictures that flip in high rates. The difference between each picture and the next is slight, and this slight difference is actually a change in the configuration of each picture.

If we want to use this as an analogy then the Universe consists of compact points, where each point can be configured to have any value of mass and energy. Therefore, the motion we see in the Universe is just an illusion that is caused by the change of configuration of each point.

This is an interesting philosophical thought, but it is too much to be real. However, we think it is useful to discuss it here to give a clear sense that motion can actually be quantized.

What we assume is happening for motion is that particles "disappear & appear" in the direction of motion through a mechanism that is yet incomprehensible. We think that this solution could be regarded as a necessary closure for Zeno's logical argument. Furthermore, the mathematical relationship between "kinetic energy" and motion could support this solution: if energy is quantized then motion should be quantized.

We will use the philosophical solution of Zeno's paradox to propose a physical model for the wave-matter duality. The "wave-matter duality" has been proposed in 1924 by "Louis de Broglie". This concept theorizes that moving particles have wave-like behavior.

It should be noted that our proposal here is not a scientific one nor philosophical, but a "lateral thinking" proposal; as it depends on the following unproven assumptions:

1# Particles move through multiple jumps. The minimum jump is one "Quanta of distance". Jumps cannot have a fraction of Quanta.

2# The distance of one Jump increases (to a limit) with speed and decreases with mass. But this distance needs to be integer multiple of Quanta. This can explain "Quantum Tunneling".

It should be noted that this does not apply to light, as photons are massless with constant speed.

3# Jumps don't necessary fall at the line of movement, but it might fall around the line (up or down the line, left or right, diagonal, etc.) This jump can be divided (metaphorically) to two equivalent jumps: one at the line, then another short jump from the line to the side of the line.

4# The length of side jumps increases with speed. This can be seen as a vibration of the particle around the line of movement. This vibration increases with speed.

5# If the particle size is large then the length of side jumps will be low compared to the particle size, therefore particle vibration will be small around the line of movement.

But if the particle size is minute then the length of side jumps will be high compared to the particle size, therefore, particle vibration will be high around the line of movement.

This is the proposal we suggest for explaining the wave-matter duality. We repeat here that this is not intentioned to be a scientific proposal nor a philosophical one, but a "lateral thinking proposal" that was inspired by the philosophical solution for Zeno's paradox.