A Model of Discrete-Continuum Time for a Simple Physical System

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Proceeding from the assumption that the time flow of an individual object is a real physical value, in the framework of a physical kinetics approach we propose an analogy between time and temperature. The use of such an analogy makes it possible to work out a discrete-continuum model of time for a simple physical system. The possible physical properties of time for the single object and time for the whole system are discussed.

Commonly, time is considered to be a fundamental property of the Universe, and the origin which is not yet clear enough for natural sciences, although it is widely used in scientific and practical activity. Different hypotheses of temporal influence on physical reality and familiar topics have been discussed in modern scientific literature (see, e. g., [1–3] and references therein). In particular, the conception of discrete time-space was proposed in order to explain a number of physical effects (e.g., the problem of asymmetry of some physical phenomena and divergences in field theory) [2–4]. Following this theme, in the present paper we shall consider some aspects of the pattern of discrete-continuum time for a single object and for the whole system. We will focus on the difference between time taken as a property of a single object and a property of the system. We would also touch upon the question of why the discreteness of time is not obvious in ordinary conditions.

As a "given" property of existence time is assumed to be an absolutely passive physical factor and the flow of time is always uniform in ordinary conditions (here we consider the non-relativistic case) for all objects of our world. Therefore classical mechanics proceeds from the assumption that the properties of space and time do not depend on the properties of moving material objects. However even mechanics suggests that other approaches are possible.

From the point of view of classical mechanics a reference frame is in fact a geometrical reference frame of each material object with an in-built "clock" registering time for each particular object. So in fixing the reference frame we deal with the time of each unique object only and subsequently this time model is extended to all other objects of concrete reality. Thus, we always relate time to some concrete object (see, e. g., [5]). Here we seem to neglect the fact that such an assumption extends the time scale as well as the time flow of only one object onto reality in general. This approach is undoubtedly valid for mechanical systems. In the framework of such an approach there is no difference between the time of an unique object and the time of the system containing a lot of objects.

But is it really so? Will the time scale of the system taken as a whole be the same as the time scale of each of the elements constituting the system? It is of interest to consider the opposite case, i.e. when time for a single object and time for the system of objects do not coincide. So we set out to try to develop a time model for a physical system characterized by continuum and discrete time properties which arise from the assumption that the time flow of an individual object is a real physical value as, for example, the mass or the charge of the electron. In other words, following Mach, we are going to proceed from the assumption that if there is no matter, there is no time.

In order to show the plausibility of such an approach we shall consider a set of material N objects, for example, structureless particles without any force-field interaction between them. Each object is assumed to have some individual physical characteristics and each object is the carrier of its own local time, i.e. for each i-object we shall define its own time flow with some temporal scale θ_i as

$$dt_i = \theta_i dt, \qquad (1)$$

where t is the ordinary Newtonian time. Generally speaking, one can expect dependence of θ_i on the physical characteristics of the object, for example, both kinetic and potential energy of the object. However, here we shall restrict ourselves to consideration of the simple case when $\theta_i = \text{const}$.

Since we associate objects with particles we shall also assume that there are collisions between particles and the value of θ_i remains constant until the object comes into contact with other objects, as θ_i may be changed only during the impact, division or merger of objects. This means that the dynamics of a single object without interaction with other objects is determined only by its own time t_i. If, however, we consider the dynamics of an i-object with another j-object we have to take into account some common time of i- and j-objects which we are to determine.

This consideration suggests that in order to describe the whole system (here we shall use the term "system" to denote a set of N objects which act as a single object) one should use something close or similar to a physical kinetics pattern where macroscopic parameters like density, temperature etc., are defined by averaging the statistically significant ensemble of objects. In particular, for the system containing N particles the temperature may be written as

$$T = \frac{1}{N}\sum_{i=1}^{N} v_i^2 - \left(\frac{1}{N}\sum_{i=1}^{N} v_i\right)^2, \qquad (2)$$

where v_i is the velocity of the i-object. For the whole system we introduce the general time τ to replace the local time of the i-object (1) as

$$d\tau = (1 + D)\, dt, \qquad (3)$$

where D is determined by the differential relation

$$D(\tau) = \left[\frac{1}{N}\sum_{i=1}^{N} (\theta_i)^2 - \left(\frac{1}{N}\sum_{i=1}^{N} \theta_i\right)^2\right]^{1/2}. \qquad (4)$$

By such a definition the general time of the system is the sum total of its Newtonian times and some nonlinear time $D(t_i)$ which is a function that depends on the dispersion of the individual times dt_i. It is noteworthy that this simplest possible statistical approach is similar to that of [6, 7].

It is quite evident that we have Newtonian-like time even if $D = \text{const} \neq 0$. Indeed, from (3) it follows that

$$\tau = (1 + D)\, t. \qquad (5)$$

The pure Newtonian case in relation (3) is realized when all objects have the same temporal scales $\theta_i = \theta_0$.

At the same time there exist a number of cases in which the violation of the pure Newtonian case may occur. For example, let us assume that we have got a system where some number of objects would perish, disappear, whilst another set of the objects might come into existence. In this case the number N is variable and we have to consider D as an explosive step-like function with respect to N, which we ought to integrate (3) only in some interval $t_0 \leqslant t \leqslant t_x$ where D remains constant. Here it is obvious that the value of such an interval $t_x - t_0$ is initially unknown. Instead of the Newtonian continuum time (5) we now get a piecewise linear continuous time which is determined by the following recurrence relation

$$\tau = (1 + D)(t - t_0) + \tau_0, \qquad t_0 \leqslant t \leqslant t_x, \qquad (6)$$

where $\tau_0 = \tau(\tau_0)$. This relation remains true whilst D is not changed. At the moment of local time $t = t_x$ the value D becomes $D + \Delta D$, so we have to redefine τ_0 and other parameters as

$$\left.\begin{aligned} &\tau_0 := \tau(t_x) = (1 + D)(t_x - t_0) + \tau_0 \\ &t_0 := t_x, \quad D := D + \Delta D \end{aligned}\right\}. \qquad (7)$$

Thus, instead of the linear Newtonian time for a single object we get the broken linear dependence for the time of the whole system if the number of objects forming this system is continuously changing.

Since in reality the majority of objects, as a rule, form some systems consisting of elementary units, it can be concluded that the number of constituent elements might change, as was shown above in the example considered. In this case D becomes variable and one deals with the manifestation of a piecewise linear dependence of time.

However, it is clear that the effects of this non-uniform time can be revealed to best advantage in a system with a rather small N, since in the limit $N \to \infty$ the parameter D becomes little sensitive to the changes in N. That is the basic reason why, in ordinary conditions, we may satisfy ourselves with the Newtonian time conception alone.

In the present paper we have tried to draw an analogy between time and temperature for the simplest possible physical system without collective interaction of the objects constituting the system, in order to show the difference in the definition of time for unique objects and for whole systems. One should consider this case as a basic simplified example of the system where the discrete-continuum properties of time may be observed. Thus one should consider it as a rather artificial case since there are no physical objects without field-like interactions between them.

However, despite the simplified case considered above, the piecewise linear properties of time may in fact be observed in reality (in ordinary, non-simplified conditions), though they are by no means obvious. In order to reveal the of dispersion time $D(\tau)$ it is necessary to create some specific experimental conditions. Temporal effects, in our opinion, are best observed in systems characterized by numerous time scales and a relatively small number of constituent elements.

The author is grateful to E. G. Believskaya, D. I. Lamden for their helpful discussions. Also, the author would like to thank I.T. Kruglak for raising problems which initiated this investigation and for his interest in the work. Also, I would like to thank the language editor of this journal for his work in correcting my manuscript.

Submitted on January 07, 2008
Accepted on January 17, 2008

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