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TIME AS A COMPUTATION PROCESS

Some properties of time may be conceived geometrically, i.e. envisioned with the help of spatial tools. But it would be incorrect to reduce the time phenomenon to space as it is actually assumed in modern physics and in the theory of unified time-space. Attempting to express the essence of time in a few words it is admissible to assert that time is a computation process. A transition from the present to the past and to the future is a result of calculations carried out by nature. Therefore computer models should be utilized as a basic means for presenting time. Unfortunately computation theories available in science today are mostly unsuitable for the purpose and demand far-reaching generalizations that concern modeling time in particular.

1. Time and order of events

The live world is a totality of events. Events take place in space and time and are reciprocally bound by different space and time relations that may be stated in appropriate utterances. For example, we may affirm that an event *s* happened *beside* an event *s'* or that an event *s* happened *earlier* an event *s'*. Space and time relations at the same time possess certain properties. Thus for no event *s* we can say that *s* happened *beside* event *s* or that *s* happened *earlier* event *s*. From the point of view of logic this means that binary relations *beside(P)* and *earlier(P)* possess a property of *anti-reflexiveness*: $\forall s \neg(s\ P\ s)$ и $\forall s \neg(s\ R\ s)$. The relation *earlier* has one more notable property. If *s earlier s'* and *s' earlier s''* then *s earlier s''*. This property is called *transitivity* and formally described as following: $\forall s \forall s' \forall s''((s\ R\ s' \ \&\ s'\ R\ s'') \rightarrow\ s\ R\ s'')$. But the spatial relation *beside* does not possess the property of transitivity. Indeed, let us put s_1 *beside* s_2, s_2 *beside* s_3, …, s_{n-1} *beside* s_n. If *beside* were transitive then it would result in s_1 *beside* s_n though evidently s_1 does not have to obligatory stand *beside* s_n. Consequently the relation *beside* is not transitive and we cannot put it like this: $\forall s \forall s' \forall s''((s\ P\ s' \ \&\ s'\ P\ s'') \rightarrow s\ P\ s'')$.

Some may find trivial everything stated above if ignorant of the fact that anti-reflexive and transitive binary relations are called relations of *partial order* in logic and mathematics. Among all possible orders it is the most primitive, but still an order. It follows that the time relation *earlier* orders events (let partially). But we know of *not a single* natural binary relation that would simultaneously be anti-reflexive and transitive. If the latter is true then **time orders events but space does not**. Thus even at the first approach to considering time and space relations we uncover a drastic difference between time and space.

Unfortunately this difference is steadily ignored in all kinds of areas of knowledge. A concept of the so-called mythical time has spread wide, which characteristic is recurrence[1]. Mythical events not only follow one another but they reoccur again and again. In some myths the creation of the world takes place more than once. At that, the order of events is being accurately repeated up until a subsequent destruction of the world. In this connection M. Eliade differs between infinite cyclic time (a succession of events repeats endlessly) and a finite cyclic time (the number of reiterations is finite; for example, the Golden Age may return but only once)[2]. Paradoxically besides myths the cyclic time may also be found in modern

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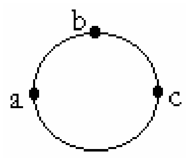
[1] See: *Элиаде М.* Космос и история. М., 1987.
[2] Ibid. P. 107.

physical theories. So, in 1949 K.Godel found a cosmological model where some time-like lines turned out to be closed[3].

This appears very fascinating but the price for assuming a concept of cyclic time is a rejection of the relation *earlier* as an ordinal relation. It is logically impossible to reconcile the ideas of cycle and order. Time may be considered either as a cycle or as an order, but not both. If we depict time as closed-loop line as shown in the picture then it is impossible to tell



which event, *a*, *b*, or *c* happened earlier. If we know about these events that one happened at 3 o'clock, the other happened at 9 o'clock and the last one at 12 o'clock but we do not know whether they occurred on one and the same day then we can say absolutely nothing about the time order of these events. Even the possibility to utilize an essentially spatial structure – a line – to model time is itself problematic. It seems legitimate only when a line's points are strictly ordered (supposedly on a line segment). But a circle's points are not ordered, because the given axioms of partial order do not apply to them. The mentioned Godel's result must be assessed, therefore, as a mathematical artifact discovered within a geometrical theory that groundlessly equates a line with time.

We encounter a rather widespread situation here. First we are presented a mathematical theory poorly matching the reality and yet exploiting well-known terms in unusual sense and then oceans of ink are issued on account of that theory's false profundity, which allegedly makes us perceive a great paradoxicality of habitual phenomena. It immediately disappears the moment when we understand the clue is solely in the assignment of untraditional meanings to terms.

The said applies not only to mathematical theories but also to concepts posed by means of natural languages. When claiming a scientific character they should use a natural language very cautiously. Even when studying myths it is unnecessary to succeed a mythical style. Otherwise, as in the currently considered case, a pseudo-scientific concept of mythical cyclic time itself turns into a myth. If we represent the infinite cyclic "time" and its finite analogue as rows …, *a*, *b*, *c*, *a*, *b*, *c*, … and *a*, *b*, *c*, *a*, *b*, *c* accordingly then it becomes plain that these cyclic chains of events are unordered and therefore cannot be time models (by the way, a row *a*, *b*, *c* is already ordered!)

So, *time either orders or does not exist at all.* The first alternative must be chosen straightaway as consistent not only with our intuitive perception of time but also with the centuries-long analysis of time in the philosophical and scientific tradition, that cannot be shaken by fashionable physical theories simply because they do not describe time. Generally upon reading an overwhelming majority of papers and books on the problem of time, an unpleasant feeling arises that we are being deluded. Often the narration relates not to time but to other phenomena though touching this way or another on time. They say "time" but actually mean light signals, periodic processes, clocks, age, mathematical structures (groundlessly declared as models of time), statements about time, procedures of time measuring, etc[4]. Here we discuss the problem of time in itself and do not substitute it for other issues however important these may be.

Meanwhile any output produced by physics will not be ignored as far as it has even a minute relation to the problem of time. One such result obtained under rather specific assumptions consists in determining of a non-absolute character of some usual time relations. It is asserted in the special relativity theory that the relation *earlier* (alongside with *after*) and the relation *simultaneous* is not absolute in meaning because one and the same pair of events *s* and *s'* may be observed *s earlier* s' in one reference frame and *s simultaneous s'* in some other reference frame which is an unthinkable thing in classical physics and traditional philosophy. From the point of view of logic we encounter a situation when instead of usual

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[3] *Gödel K.* An Example of a New Type of Cosmological Solutions of Einstein's Equations of Gravitation. "Reviews of Modern Physics", Vol. XXI, 1949.
[4] For details see: *Анисов А.М.* Время и компьютер. Негеометрический образ времени. М., 1991.

binary relations *earlier* and *simultaneous* we get *ternary* relations: *s earlier s' in the reference frame k* and *s simultaneous s' in the reference frame k'*. Now the statements *s earlier s' in the reference frame k* and *s simultaneous s' in the reference frame* k' may both be true for specific s, s', k, and k'. And this contains no paradox as far as $k \neq k'$. It is quite another matter that the time order argumentation laid above refers to binary but not ternary relations. However the binary essence may be easily restored. Let us denote the relation *earlier* with E and define $s\ E\ s' \leftrightarrow_{Df} \neg\exists k$(*s simultaneous s' in the reference frame k*)) & $\exists k$(*s earlier s' in the reference frame k*). Likewise denoting the relation *simultaneously* with S its binary character becomes restored: $s\ S\ s' \leftrightarrow_{Df}\ \neg(s\ E\ s')\ \&\ \neg(\ s'\ E\ s)$. What is the physical sense of the just accomplished procedures? It is quite transparent. We propose to assume that *s earlier s'* only when *s* and *s'* are linked by a time-like or light-like interval and that *s simultaneous s'* only when *s* and *s'* are linked by a spatial-like interval. In other words *s earlier s'* if *s* can physically influence *s'* and *s simultaneous s'* if *s* cannot physically influence *s'* and *s'* cannot physically influence *s*.

An analogous approach to synchronism is offered by H.Reichenbach[5] though for a definition of synchronism he uses what we have as its intensional comment. A more formal approach laid down here makes a fact evidently overlooked by H.Reichenbach plain. In a classical understanding of synchronism (let us denote it with H) this relation is reflexive ($\forall s(s\ H\ s)$), symmetrical ($\forall s\,\forall s'(s\ H\ s' \rightarrow\ s'\ H\ s)$) and transitive ($\forall s\,\forall s'\,\forall s''((s\ H\ s'\ \&\ s'\ H\ s'') \rightarrow\ s\ H\ s'')$). A reflexive, symmetrical, and transitive relation is called a relation of *equivalence*. But resulting from the special relativity theory the relation of simultaneity S being reflexive and symmetrical (such relations are called relations of *resemblance*) does not possess the transitivity property. Let us consider a following counter example. Imagine that you shoot (event *s'*) and break a window (event *s''*). It is clear that $s'\ E\ s''$. Let a light event *s* happen somewhere at a distance (say on Jupiter) so that a flash from the shooting cannot reach *s* on time, and also the light from *s* cannot reach neither *s'*, nor *s''* timely. Then $s\ S\ s'$ and $s\ S\ s''$. Owing to the symmetry $s'\ S\ s$. If we had transitivity then from $s'\ S\ s$ and $s\ S\ s''$ we would get $s'\ S\ s''$, which is impossible because $s'\ E\ s''$. Therefore the relation of resemblance S is not a relation of equivalence.

Why is it so important? The point is that each equivalent relation on any arbitrary non-null set corresponds to its dissection into non-null non-intersecting classes. Likewise the classical relation of simultaneity H assigned on a set of events also conforms to a dissection of this set into non-null non-intersecting classes. These non-intersecting classes of simultaneous events can be logically considered time moments. More precisely, we call *a time moment t* a set of all events simultaneous with *s*: $t_s =_{Df}\ \{v|\ v\ H\ s\}$. Since the events are partially ordered by the time relation R this order induces a corresponding order relation on the set of moments of time: let $t_s\ \boldsymbol{R}\ t_{s'} \leftrightarrow_{\mathrm{Df}} s\ R\ s'$. No such thing is possible with the non-transitive relation S and, therefore, it is senseless to introduce a natural definition of a time moment as a set of simultaneous events in the special relativity theory. We regard this fact a serious logical reason to not recognize this theory as a time theory. Interesting that following other argumentation than stated in this paper some physicists in this or that respect come to similar conclusions. "…Close attention in the special relativity theory, – says W.Burke, – is paid not to time but clocks…"[6]. This is a notable confession allowing for the fact that the quoted book stands far from philosophical problems.

An objection may be put forward that the special relativity theory drastically alters traditional notions of time. Furthermore it is seemingly implied that traditional concepts of time are faulty and, therefore, from now on they should be replaced with the only true one – the one used in the relativity theory. This common opinion is inconsistent in two aspects at the least. First, it is doubtful from the point of view of logic. When we are not satisfied with a

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[5] Reichenbach H. Philosophy of Space and Time. N.Y., 1958. Chapter II, §22.

[6] *Burke W*. Spacetime, Geometry, Cosmology. University of California, 1980. Chapter I, §8.

traditional concept *A* and we want to replace it with a concept *B*, then it is better to use a new term for the concept *B* than leaving the same one in use. It is a usual way in science. When it was discovered that the Earth's shape was not strictly spherical a new term was picked to denote it – the geoid. Now imagine that someone insists that since geology has changed the idea of the Earth's shape and what was earlier called a sphere is now something else then further on it becomes necessary to call geoid a sphere. Second, the discussed standpoint is factually false because in actual science the traditional approach to the problem of time is still in use and being developed, and it does not blend into the existing physical theories entirely. We have in view time concepts that take shape in geology, evolution biology, civic history, and many other sciences that may be called *historical* in a wide sense. An arrogant disregard of the output of these sciences is fraught with negative outcome to the prestige of physics as already used to be. Remember a famous debate about the Earth's age when physicists (Lord Kelvin the first among them) relying on trustworthy physical theories allowed the existence of Earth no more than one hundred and a half million years while biologists and geologists according to their theories required at least a degree more than that. And who turned out to be right in the end?

Before proceeding to discuss time concepts in historical sciences it is necessary to make several notes about time order. As has been mentioned above there is a relation of partial order on a set of time events. Let us now answer the question what the specific type of this order is. The most widespread assumption in science is that time moments are ordered *arcwise*. Logically it is expressed by the formulae $\forall t \forall t'((t\, \boldsymbol{R}\, t' \vee t' \boldsymbol{R}\, t \vee t = t')$. But events do not form an arcwise ordered totality with the relation *earlier* (be it *E* or *R*). The arcwise order in the set of time moments allows the application of the following procedure: a set of time moments *T* with the relation ***R*** (i.e. a pair $\{T, \boldsymbol{R}\}$ may be substituted with a number set *Z*, which is ordered arcwise by the relation *less* < (a pair $\{Z, <\}$); at that it is supposed that the systems $\{T, \boldsymbol{R}\}$ and $\{Z, <\}$ are *isomorphous*. Now we can date events, tell how long one event precedes another, and so on. Usually a set of real numbers is taken for *Z* though in practice measuring time cannot lead beyond the scope of the rational number scale. In any case each corresponding number order has neither the first, nor the last element which conforms to the idea of time without beginning or end. Altogether there are no special points or time moments marked by order relations on the time scale.

2. Historical time scales

How realistic are these time scales devoid of marked points and how close do they fit the real state of affairs in our universe? Here it becomes necessary to remind about the starting issue of all the temporal structuring undertaken in this paper – about the basic notion of event. In addition to other distinctions various sciences differ in what classes of events they study. For better understanding of the problem of time it is very important to distinguish between two kinds of events comprising the totality of all events. There are events that happen *repeatedly* in time and there are events that happen only *once* and cannot recur at least within the limits of the foreseeable time. A flash of light, a thing dropped, a collision of particles – these are events of the first kind. The origination of the Solar system, the extinction of dinosaurs, the crossing of Rubicon by Julius Caesar – are events of the second kind. Even neokantians H.Rickert and W.Windelband noticed the division of sciences into two groups depending on whether they mainly studied recurrent events or unique events that had place only once in the course of time. W.Windelband called the first group *nomothetic* and the second one – *ideographical*[7].

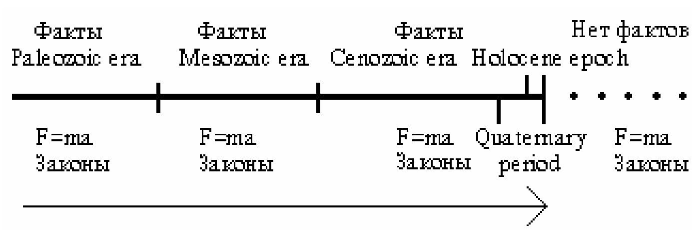
One may think that proper names play a special part in describing unique and non-recurrent events in time but the example of the dinosaurs' extinction shows that a unique

[7] *Виндельбанд В.* Прелюдии. Философские статьи и речи. СПб, 1904.

event may be identified without using any proper name at all. On the contrary a repeated event may require its own proper name, for example, an event “Socratus is sitting”. This example leads to think that among repeated events it is necessary to distinguish events recurrent on a certain time interval (Socratus was sitting many times in his life but not beyond its limits) and events that can happen beyond the scope of any time interval given in advance (for example, explosion). It is exactly the events possessing a capability to repeat unlimitedly that give birth to geometrical conceptions of time as an infinite line with no special or marked points. It is quite another matter regarding unique events. They force to build time scales with special points or intervals. When physicists first engaged in studying a unique event – the origination of the meta-galaxy – then immediately a scale appeared with a marked *initial* moment of time.

Even more wonderful are time scales in history sciences that take interest in unique events in particular. On such scales there are *terminal* moments or intervals. There is a certain canonical example of such a scale. It is the scale of geological time which has the history of life on the Earth at its heart.

On this scale (many details unimportant for the analyzed problem are omitted, particularly such opening sections as Archaean and Proterozoic eras) time comes to its end at the Age of Mammals, Quaternary period, Holocene epoch. Nothing follows – the succession of eras, periods, and epochs is cut off. It is easy to perceive the p*resent* in the epoch of Holocene on this scale, the *past* – in the preceding eras and periods, and finally the *future* – in the empty area of missing unique facts. The line of physical time depicted below represents naturally repeated physical events and utterly disregards the very existence of unique events. That is why the sections of the past, the future, and the present moment is absent on this line.



The mentioned peculiarities of the geological scale are not specific but rather essential to any scale of *historical time*. In history time is represented with a scale featuring the terminal element – an interval “now”. It is exactly an interval because the present has duration in history which can be shown with the help of shorter time units. Thus the present of political history may be constituted by minutes or even seconds but it would be nonsense to consider political events on the split second scale. The present of economical processes lasts longer. Even longer is the present of geological processes and so on.

Now the question is which of the two scales displayed has a better reason to be *called* a time scale. Apparently it is the first one. Because on this very scale such essential attributes of time as the past, the present, and the future are plainly represented. The second scale that constitutes an endless line extending in both directions resembles space and conveys no specific temporal information. Time abstracts are attached to it outwardly. Sure, the first scale is also spatial but it represents a system of specific stretches that have no independent meaning in geometry (unlike the notion of a line). Moreover it is the first scale in particular that indicates a necessity to switch to non-geometrical means of time representation as will be shown below.

Let us now return to the problem of interrelations between time scale and reality. Which of the two time scales does *display more precisely* the characteristics of the real universe? There are many adepts in philosophy and science who would prefer a scale of physical time without doubt. They might not know of the scales of historical time. What will they say having read this paper, though? Alas, it is unlikely that they would alter their standpoint. For many people it is physics alone that gives the most unbiased description of reality. But are other sciences – say, geology – less impartial? Quite on the contrary, the awareness of resemblance between modern physics and oriental philosophy, the antropic principle, the admission of the observer into the process of investigating the physical reality, and similar ideas make physics more and more subjective. We assert again with all responsibility that the scales of historical time described above are a final outcome of empirical scientific analysis and have not an ace of perceptual psychology of time or consciousness characteristic. Historical time scales are entirely objective and we have no ponderable reason to doubt their verity: they resemble *temporal* peculiarities of the live world that result from the existence of unique events consistently true.

Does it follow that scales of physical time do not represent reality and therefore should be rejected as phantom formations? Not at all. It must be understood that the real world besides temporal also has *non-temporal* features bound to the class of repeated typical events. Physics describes these events. Even time physics considers in a geometrical and thus essentially non-temporal sense. The abuse of physics comes when it is asserted peremptory that physics alone and nothing else can reveal the objective properties of time and that time appears exactly like it is described in physical theories. But what time do we call *time* that has no impartially distinguished present or past or future?

3. The phenomenon of becoming

Time has one more fundamental quality. We can feel the flow of time, we say that time goes by or passes. Is *the stream of time* or *becoming in time* possibly an illusion of our consciousness? Physicists assume so. However having admitted that history time scales describe objective features of the real world which exist independent of an individual we successively ought to admit the objectiveness of the stream of time or becoming. Indeed the present moment making up the end of these scales will most certainly cease to be terminal. In the stream of time this moment will slide into the past and will be replaced by another present moment comprising a host of new unique events. But the fresh present does not emerge from a ready-made future. An important note: historical scales *do not contain the future – it does not exist as a formation filled with unique events*. What is the future then? The future is what nature still has to create. Keeping in mind our ability to percept such phenomena it is better to put it like this: **the future is being *calculated* by nature**. As soon as the next computational stage is over we get a new present.

The idea of representing objective time as a natural computational process requires detailed elaboration that is difficult to implement both conceptually and technically. Here we stand at its very beginning. Besides that the article's limits make us confine to only some significant comments and logical constructions. What to begin with? Let us try to start with what we would usually finish – with the problem of *resources*. Before issuing a new future the natural computer should have enough free space for placing it. But there is already *no room* in the event space. Therefore in order to station the future made in the course of calculations it is indispensable to get rid of at least some events *beforehand* thus freeing the space needed. **The destruction of a part of events by nature is *calculating* the future**. Hence it is not only the future but also the past that results from the computational process.

Calculating the past and the future makes up a consistent sequence of stages of becoming. Let the *first stage* contain an ordered set M consisting of time moments' events only one of which is a present moment h. Also let M occupy *all* available room for placing events – in this case we call M a **present meta-moment**.

Since no new events can be placed in the universe then at the *second stage* some events are being erased from each moment of time (including the present moment h). These events are not stored in any special containment but *disappear* from the universe in the true sense of the word because there are no free resources for keeping them. The elimination of a part of events results in a structure M' containing the rest of the former present h' that has some room for placing events unoccupied – we call this structure a **past meta-moment**.

At the *third stage* a new moment of time h is being formed that directly follows h' (it means that $h' R\ h$ and $\neg\exists t(h' R\ t\ \&\ t\ R\ h)$) and is being filled with new events while the universe still has enough free space for that. Other moments of time are not engaged in the process (because the future can add nothing to the past but only subtract from it).

As soon as all resources for event allocation are exhausted a new present meta-moment M is formed containing a present moment h which means reversion of the process back to its first stage. Then everything repeats anew.

The stages of becoming thus make a *close-loop cycle* that has no termination. The universe of events recurrently passes through the present state, drops to the past, and, when in the future mode, it is being updated to a new present. Even this *extremely simplified* view of becoming in time reveals how far it stands from the overly primitive geometrical concept of time. Here arise many questions that generally cannot be posed for static geometric structures. For example a problem of *feasibility* of a next stage of becoming gains utmost importance. The process may well come to such a critical situation when because of a logical impossibility to complete a next transformation of the universe of events the stream of time would be cut off in a state of logical emergency stop. Therefore the future is not guaranteed, **it may not come**! This possibility is nothing else than the idea of the *doomsday* that however emerges not from religious reasons but in the frame of science.

One more implication of the proposed concept of time as a computational process is the assertion of a *quantified* nature of the temporal series. Any calculation is a quantified sequence (sometimes recurrent) of stages (at any rate we stand for this strictly general idea of calculation) and time makes no exception. According to the picture of the third stage of becoming a new present is discretely added to what remains of the temporal scale – the past meta-moment – thus making a new present meta-moment. However in spite of a discontinuous replenishing of new time moments that goes again and again the whole meta-moment construction does not grow because what is added precisely fits what has just been removed. Indeed becoming is running on the spot.

In this respect the problem of time *direction* and the possibility of its *inversion* acquire a new perspective. On the one hand meta-moments "advance" in the direction of the future (every third stage of becoming). On the other hand the same meta-moments slide back into the past (every second stage of the cycle). Then what direction does time flow in? And what sense has the inversion of its flow now? That sometime in the future there would appear a present time moment which had already been in the past and then was destroyed entirely or partially? Or that the procedures on events are inverted: replenishment takes place of elimination and elimination substitutes replenishment? We made an attempt to consider these problems in a separate paper[8] but much remains unclear yet.

A problem of time's *beginning* turns out to be quite peculiar within the time concept under consideration. Geometrical time models do not present such a problem because it is always possible either to assume an initial time moment t_0 or postulate the absence of such a moment. It is a much more complicated issue when applied to computational models. As far as we know all currently proposed computational theories and their generalizations are based on one indisputable assumption that any calculation should have a first stage of implementation (a calculation may be finite or, conversely, infinite though it is still another problem). Nevertheless it seems not quite right if a computational theory's peculiarities predetermined the question of existence or absence of a beginning in respect to becoming in time.

The list of questions and problems may be continued further on. But what has already been set out is enough to make certain that in many aspects the proposed time concept offers an entirely new problematic system. Within the borders of this article the description of the

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[8] *Анисов А.М.* Направленность и обратимость времени // Логические исследования. Вып.6. – М., 1999. С. 195-217.

process of becoming is simplified to the limits[9]. Even the time order was displayed too unsophisticatedly which will be discussed in the next paragraph.

4. The broom of time

Historical time scales have a disadvantage of lacking a representation of the future. Meanwhile the future does exist in a certain way but other than the present and the past. The experience of the live world surrounding us leads to conclude that the future is a certain aggregate of alternate progress scenarios. Starting with the present moment begins a *bifurcation of time into the future*, where every branch constitutes a possible variant of a future state of affairs. Let us formally set out this idea.

Let symbol h stand for a *present* moment, symbol R denote the relation *earlier*; also it is necessary to introduce the following abbreviations:

$t \nabla t' \leftrightarrow_{Df} t R t' \vee t' R t \vee t = t'$ (comparability of time moments t and t′);

$t \mid t' \leftrightarrow_{Df} (t R t' \vee t' R t) \& \forall z(\neg(t R z \& z R t') \& \neg(t' R z \& z R t))$

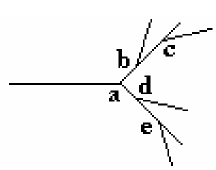
(t and t′ – adjacent moments of time).

Let us assume the following axioms of time order:

1. $\forall t \neg(t R t)$
2. $\forall t \forall t' \forall t''(t R t' \& t' R t'' \rightarrow t R t'')$
3. $\forall t(t \nabla h)$
4. $\forall t \forall t' \forall t''(t' R t \& t'' R t \rightarrow t' \nabla t'')$
5. $\forall t(\exists t'(t' R t) \rightarrow \exists t''(t'' R t \& t'' \mid t))$
6. $\forall t(\exists t'(t R t') \rightarrow \exists t''(t R t'' \& t \mid t''))$
7. $\exists t \exists t' (h R t \& h R t' \& h \mid t \& h \mid t' \& \neg(t \nabla t')$

This settles a list of axioms. Apparently axioms 1 and 2 assert that the relation R is a special order relation. A comparability of the present moment h with any time moment results from axiom 3. In particular each time moment unequal to h is either earlier than h or later than h. Axiom 4 forbids bifurcation into the past (it is agreed to be referred to as the linearity of time into the past). Axioms 5 and 6 state that the relation R is discontinuous both in the direction of the past and in the direction of the future. Finally axiom 7 says that time bifurcates into the future starting precisely from the present moment h.

A simplified graphical model of the system of axioms is represented in the picture. The property of discontinuity is not shown though. Instead the model illustrates that time has a present moment **a** = h, an ordered linear historical interval (all moments of time on the left of the present moment of time **a**), and a bifurcation area that contains possible future (all time



moments on the right of **a**). The description of the process of becoming now appears increasingly complicated: it must include a step of choosing a specific future branch (either directed towards **b**, or towards **d**). Since the past is linear, a decision in favor of one of the branches ensues the destruction of the other, ignorable branch. For example the choice of **b** leads to the elimination of the branch containing time moments **d** and **e**. However the time moment **c** retains a chance to turn into a present moment sometime. The model also illustrates the property of linearity into the past: moving to the left from time moments **c** or **e** will be unequivocal.

The mentioned removal of ignored branches is of great importance for an adequate understanding of the phenomenon of the past. Earnest historians come to a conclusion that *history does not allow of subjunctive mood.* Any argument about what would have happened if dinosaurs did not extinct, if Napoleon was killed in his youth, or if Lenin was arrested in 1917 by czar's authorities, – contain no scientific meaning and may not have any. The offered axioms of time order precisely express this specific aspect. The past has no valid alternatives

[9] This problem is thoroughly considered in: *Анисов А.М.* Время и компьютер.

even given that sometime back certain past meta-moments contained the listed events in the zone of real possible future. The essence of the issue is in the impossibility to return back to such meta-moments. They do not exist any longer as live reality. Therefore it is generally unfeasible to trace any chain of probable historical consequences of such events.

As a whole the proposed partially ordered structure of time moments resembles a broom. So we suppose to replace the hopelessly outdated metaphor of the *time arrow* with a new one of the *time broom*. An extra reason for this besides that time comprises the past along with the present (the broom's handle) and also a variety of futures possible for a current meta-moment (the broom's bristles) is that time makes losses irretrievable. It pushes physical objects and living organisms including people into the past thus making them inexistent. In other words the time broom sweeps and nothing in the world can elude its devastating touch.

5. ABT-computability

In the concluding paragraph a brief description[10] of the syntax and semantics of an abstract programming language ABT will be set out. This language may serve as a more adequate tool for simulating the stream of time than any other currently used programming languages essentially going back to the idea of computability proposed by A.Turing. The ABT language with its substantial specificities is unrealizable on existing computer platforms. Instead it is suitable for modeling processes that have no initial stage of execution as will be shown further.

In the proposed approach to computability the key notions will be *event* and *process*. Let us maintain that events are not held within the time stream but will be expressed by sentences of the first order quantificational logic, set theory and theory of models that have no reference to time. Unlike events processes generate time stream by themselves and are capable to affect events in such a way that an actual set of events (events existing "now") is being changed in the course of the process implementation. The existence is postulated of a multitude of *elementary* processes, each of these being executed during one calculation step by an abstract computer. All other processes are assumed to be composed of elementary ones. By definition *a process* – is a linear discontinuous sequence of elementary processes.

Let us also bring into consideration ideal (contrary to real) computational devices – abstract computers. Every abstract computer @ is a consistent pair of the kind <Mm, Pr>, where Mm – is its memory for placing results of calculations and Pr – is its processor that carries out the needed calculations. Since the term "computation" is considered unlimitedly broad here the volume of the memory Mm and the potential of the processor Pr are also free from any limitations ensuing from requirements of finiteness, constructiveness and the like. Instead we maintain that abstract computers are capable of solving any transformations allowable by the set theory and the theory of models. And in this very sense we adopt the term "computation" applying to abstract computers. However it is indispensable that a sequence of such transformations should be a linear discontinuous chain of stages, i.e. a process in the sense assumed here.

It is permitted to use any non-null sets of arbitrary power for an abstract computer's memory bank. Specifically the memory Mm of the computer @ =<Mm, Pr> may be of innumerable power.

By definition Mm(S) – is a subset of the set Mm that indicates how many memory cells (elements of Mm) are occupied by harboring an object (set) S:

$$Mm(S) \subset Mm.$$

[10] A complete description may be found in: *Анисов А.М.* Абстрактная вычислимость и язык программирования АВТ // Логические исследования. Вып. 3. – М., 1995. С. 233-256.

But what if the object S was not actually allocated in the memory Mm? Then it is natural to assume that for allocating S not a single memory cell has been used, i.e. that $Mm(S) = \varnothing$. In other words the object S id allocated in the memory Mm only when $Mm(S) \neq \varnothing$.

The last condition imposed on the set of the kind Mm(S) concerns the problem of placing two or more objects in the memory bank. When it is needed to allocate sets S and S' in the memory Mm (by a single step or successively set after set) then we assume that they will occupy non-intersecting areas of the memory Mm only if these sets differ from each other:

$$S \neq S' \rightarrow Mm(S) \cap Mm(S') = \varnothing.$$

But when S = S' then obviously Mm(S) = Mm(S'). What shall we do then if we need to place several copies of one and the same object in the memory? The solution is simple: a required quantity of samples should be indexed somehow and then allocated in a computer's memory. If, for example, we need two copies of a set S then we may allocate objects <S, 0> and <S, 1> in the memory. While $<S, 0> \neq <S, 1>$ this ordered pair will occupy non-intersecting areas of the memory.

The allocation of theoretic-multiplex objects in the memory as well as their removal from the memory is controlled by a processor-executed program written in the special language ABT – the abstract programming language. We shall not concern ourselves with the inner workings of the processor Pr capable of executing any ABT program. Also we shall assume that ABT programs are allocated outside the memory Mm and that Mm stores the computation results only. In defense of the latter assumption it may be stated that it is things and events that occupy physical space while physical laws traditionally are not considered as objects capable of consuming space. Likewise ABT programs will rather play a part of laws than things or events (facts). A special kind of laws though. It is not always necessary to regard laws of nature as datum. They may be viewed as certain prescriptions to operation, prescriptions, strictly executory by nature. Hitherto nature has succeeded in "calculating" future unerringly. The question is whether it will manage this henceforward.

Let us call the computers capable of executing ABT-programs ABT-computers. Let us single out an especially important postulate concerning ABT-programs and ABT-computers.

Existence axiom:

An object can appear in the memory Mm or disappear from it only as a result of executing a corresponding operator of the language ABT by processor Pr

ABT programs are by definition finite sequences of instructions

I_{i0}
I_{i1}
.
.
.
I_{in}

(where $i_0, i_1, ..., i_n$ - are real numbers and $i_j < i_k$, if $j < k$) which are executed one by one from the top to the bottom if no command is issued to alter the order of their execution.

Every instruction generates an elementary process and contains either a single operator of the language ABT or is represented in the form of a compound operator

IF *condition* **THEN** *operator*,

where IF … THEN has a usual meaning (like for example in the programming language BASIC). Let us accentuate that this compound operator is also executed in a single step and accordingly generates an elementary process. For a *condition* it is allowable to take any set-theoretic and model-theoretic formula.

The GOTO operator. It is a well-known operator of unconditional transition. It is used in ABT-programs in the strings of the kind

GOTO Ij,

where Ij - is one of the instructions of a given ABT-program. Its function does not differ in any way from the function of similar operators in other programming languages.

ABT-programs are finished with the operator END. Upon executing an instruction **END** the respective ABT-program stops functioning. At the same time all objects allocated in the memory of the ABT-computer that have been stored there in the course of execution of the program remain in place.

The following two operators are specific to ABT language and therefore their characteristic will be more detailed.

The selection operator CHOOSE. It is used in ABT-programs as a construction

CHOOSE *list of variables* | *condition*

Here *condition* means the same as in the case of the operator IF … THEN with the exception that this *condition* must comprise **all** variables from the *list of variables* and these variables should not be **dependent** (i.e. the condition should not contain quantifiers on these variables). The *list of variables* also has restrictions: it should not contain multiple entries of one and the same variable and it cannot contain variables which values are **already** allocated in the memory Mm. Since the question which variable's value is stored in the memory Mm requires an analysis of the execution thread of a respective ABT-program the latter restriction has not a syntactic but a semantic meaning.

Formally the syntactic structure of the operator CHOOSE may be represented with a string

CHOOSE $X_0,X_1,X_2,...,X_n$ | *condition*$(X_0,X_1,X_2,...,X_n)$,

where Xi – is some variable and variables Xi and Xj are different if i≠j. The whole expression reads as "Select objects (sets) $X_0,X_1,X_2,...,X_n$ such that the predicate *condition*$(X_0,X_1,X_2,...,X_n)$ holds true)".

Let us formulate a general feasibility condition for the operator CHOOSE. If a processor Pr of an ABT-computer @=<Mm, Pr> executes a syntactically correct instruction of the kind

CHOOSE $X_0,X_1,X_2,...,X_n$ | *condition*$(X_0,X_1,X_2,...,X_n)$

and a *precondition* P

$Mm(X_0)=\varnothing$ & $Mm(X_1)=\varnothing$ & $Mm(X_2)=\varnothing$ &...& $Mm(X_n)=\varnothing$

is **false** the execution is aborted: an **emergency shutdown** takes place.

If P is **true** then the processor Pr will attempt to select (choose) such objects (sets) $S_0,S_1,S_2,...,S_n$, that being assigned as values to corresponding variables $X_0,X_1,X_2,...,X_n$ will provide *the verity of the condition* of the instruction I. Then the processor Pr attempts to *allocate* the objects $S_0,S_1,S_2,...,S_n$ in the memory Mm.

If there **exist no** objects (sets) $S_0,S_1,S_2,...,S_n$ that satisfy the *condition* of the instruction I and capable of being stored in the free memory Mm then the execution of I will be **aborted**. Otherwise (i.e. when the required objects **exist** and there is **enough** memory for their allocation) the execution of I is completed successfully into a state where the following *post-conditions* are **true**:

$Mm(Si) \neq \varnothing$ for all i, $0 \leq i \leq n$;

condition$(S_0,S_1,S_2,...,S_n)$.

Let us give an example of a specific ABT-program. Let us assume that T is a theory in nothing more than an enumerable language of the first order predicate calculus. Let us consider a syntactically correct program

I_1 **CHOOSE** X | (X |= T)

I_2 **GOTO** I_1

The execution of the first instruction consists in selecting a model of the theory T. But if the theory T is inconsistent then it has no model and the execution of I_1 will come to an emergency stop according to the semantics of the operator CHOOSE. However supposed that the theory T has a model it does not guarantee a successful execution of I_1 yet. For example if the memory of an ABT-computer that runs the given program is finite and the theory T has no finite models an attempt to execute I_1 will lead to an emergency termination.

Let the memory Mm be enumerable now (i.e. $|Mm| = \omega$). If the theory T is consistent then according to theorems of logic there exist enumerable models of the theory T. One of these models will be found by the processor Pr and allocated in the memory Mm. But if the memory was non-enumerable and T had an infinite model then the processor Pr might choose between non-isomorphic models of the theory T, for beside enumerable models the theory T would also possess non-enumerable ones. But it is generally unpredictable which of the possible outcomes will result from execution of the instruction I_1 before running it and therefore when using the operator CHOOSE we get into a situation of **non-determined alternative**. In a certain sense the operator of selection CHOOSE is similar to the axiom of selection: they are united by a non-constructive (in the meaning of mathematical constructivism) character of result derivation.

On condition that the execution of the instruction I_1 of the ABT-program under consideration is successful the processor Pr will pass on to the instruction I_2 that returns the thread execution to the instruction I_1. As soon as this GOTO transition is accomplished the thread is aborted. Why? Because $Mm(X) \neq \varnothing$ after the first running of the instruction I_1. Moreover by definition the operator CHOOSE cannot apply to a variable the value of which has already undergone a selection procedure and has been allocated in the memory Mm. So irrelevant to whether the theory T is inconsistent or not, the given ABT-program will shutdown on emergency.

Apparently along with an operator for choosing objects and placing these objects in the memory of an ABT-computer there must be an operator to cancel the results of the previously performed selections and to release the memory for allocating new objects.

Operator of releasing objects DELETE. Its syntax is utterly simple:

DELETE *list of variables*

where the *list of variables* does not contain **multiple** entries of one and the same variable (this limitation is not fundamental though it simplifies the syntax and retains succession to an analogous limitation of the operator CHOOSE). The same may be represented in the other form.

DELETE $X_0,X_1,X_2,...,X_n$

Let us now define the semantics of the given operator.

If the processor Pr of an ABT-computer @=<Mm, Pr> performs a syntactically correct instruction I of the kind

DELETE $X_0,X_1,X_2,...,X_n$,

and a *precondition* P

$$Mm(X_0)\neq\varnothing \;\&\; Mm(X_1)\neq\varnothing \;\&\; Mm(X_2)\neq\varnothing \;\&\ldots\&\; Mm(X_n)\neq\varnothing$$

is **false** the execution will be **aborted on emergency**.

If P is **true** then the processor Pr will complete the execution of the instruction I into a state where a following post-condition will be **true**:

$Mm(Xi) = \varnothing$ for all i, $0 \leq i \leq n$.

Let us use the operator DELETE to modify the previously considered sample of an ABT-program and assume that the theory T has a model and the memory Mm is infinite.

It is possible to insert an instruction containing the operator DELETE into the program that consists of only two lines in three ways.

(π1)	(π2)	(π3)
I_1 **CHOOSE** X| X |= T	I_1 **CHOOSE** X| X |= T	I_1 **DELETE** X
I_2 **GOTO** I_1	I_2 **DELETE** X	I_2 **CHOOSE** X| X |= T
I_3 **DELETE** X	I_3 **GOTO** I_1	I_3 **GOTO** I_1

Evidently the ABT-program π1 will not work successfully because of the same impediment that haunts its first variant. However the ABT-program π2 is alright: having chosen a model of the theory T following the instruction I_1 the processor Pr passes to execute the instruction I_2. Because at this moment the precondition $Mm(X) \neq \varnothing$ is true the processor Pr completes the instruction I_2 in the state of $Mm(X) = \varnothing$ and then performing the instruction I_3 GOTO it will pass to I_1. Since the precondition $Mm(X) = \varnothing$ is true the instruction I_1 will be performed again and the thread of the program $\pi 2$ will never end.

There remains the third alternative to analyze. In order to execute the ABT-program $\pi 3$, the processor Pr must *first* perform the instruction I_1 which is possible only when $Mm(X) \neq \varnothing$. But according to the postulate of existence an object X may appear in the memory of an ABT-computer only as a result of running the operator CHOOSE that will be executed *after* the operator DELETE in the program $\pi 3$. We see that the instruction I_1 containing the operator DELETE *precedes* the instruction I_2 consisting of the operator CHOOSE.

It may seem that an undisputable conclusion ensues from what has been stated: an attempt to execute the ABT-program $\pi 3$ will end in an emergency shutdown. Nevertheless it is so only on condition that we assume a process of performing an ABT-program *ought to have* a beginning. When applied to usual computers and programming languages the appropriateness and even the necessity of such an assumption is undoubted. But in the case of ABT-computers and ABT-programs it does not appear that indispensable.

Indeed let us suppose that the thread of the ABT-program $\pi 3$ has no start, i.e. any current execution of any instruction of the program $\pi 3$ has been preceded by an infinite number of performances of this instruction. This supposition is consistent and therefore quite admissible. Hence before running an immediate instruction I_1 the processor Pr has completed the instruction I_3 and before that – the instruction I_2 after which the ABT-computer has entered a state of $Mm(X) \neq \varnothing$. The GOTO transition to I_1 has retained this state which provided the verity of the precondition of the operator DELETE. After a successful execution of I_1 an assertion $Mm(X) = \varnothing$ becomes true which is required for performing I_2 and so on.

This process can be displayed as follows:

$$..., I_1, I_2, I_3, I_1, I_2, I_3, I_1, ...$$

Thus comprehended the process of the program $\pi 3$ has neither a beginning nor an end, contrary to traditional computational processes that indispensably start sometime. However will the program $\pi 3$ run? An affirmative answer ensues from assuming a following postulate.

The postulate of feasibility:

If the assumption that an ABT-program π is feasible contains no inconsistency then the program π is feasible

An interesting difference between ABT-programs $\pi 2$ and $\pi 3$ consists in that $\pi 3$ may be performed only on condition that the thread has no beginning while $\pi 2$ is feasible irrelevant to whether it has a beginning or not. A hypothetic process $\pi 2$ that has the first stage was described above. But a description of an imaginary process $\pi 2$ that has no start almost entirely reiterates a corresponding description of the process $\pi 3$. We speak of hypothetic or imaginary processes $\pi 2$ because if we assume the existence of processes that have no beginning along with “ordinary” processes then there would be no unequivocal answer to the question what kind of process is being performed when running $\pi 2$ on an ABT-computer. It may be either the first or the second kind of the process alike.

The discussed difference has an important meaning in application to philosophy. So far the problem of time beginning has no solution that would satisfy all researchers. If a thesis is adopted that this problem is insoluble than for modeling time stream a construction resembling the program $\pi 2$ is more adequate; the adoption of a thesis that time has no beginning makes applicable programs of the kind of $\pi 3$. Finally the programming language ABT allows to express the idea of time beginning easily. It suffices to insert an instruction that runs only once before performing an endless cycle. For example in the case of the program π2 it is enough to add an instruction GOTO I_1 to the list of its instructions.

(π4)

I_0 **GOTO** I_1
I_1 **CHOOSE** X| X |= T
I_2 **DELETE** X
I_3 **GOTO** I_1

A resulting ABT-program π4 is feasible only in the course of a process possessing a beginning. Indeed the first instruction to be executed is I_0, and then an infinite cycle starts. Schematically it may be shown as follows:

$I_0,I_1,I_2,I_3,I_1,I_2,I_3,I_1, \ldots$.