Internal Time as an Operational Structural Parameter in Adaptive Systems

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Abstract: This article introduces the concept of internal time as an operational structural parameter in adaptive systems. Internal time is interpreted not as an external time scale, but as a measure of the duration of the coherent context of the system, based on its structural stability, causal reliability, and memory. The analysis is based on the latest architectures of adaptive control D^3A (Directional - Deformation - Dissipation Architecture) and ΔE-CAS-T, developed within the framework of the Petronus project and the Synthetic Conscience protocol (author - Maxim Barzenkov). It is shown that the shortening or interruption of internal time leads to the accumulation of structural drift, the loss of regime stability, and failures in the stabilization of adaptation. At the same time, a sufficient length of internal time locally dampens drift, whereas its shortening turns drift into a trigger for the system's transition into a new regime. Conditions are formulated under which a system can stably exist in a coherent regime without losing consistency. A fundamental difference of the proposed approach from classical problems of model mismatch (sim2real, model mismatch) is noted: it is structural, not statistical incompatibility that is considered. It is concluded that without accounting for the factor of internal time it is impossible to guarantee the coherence of adaptation over long horizons.

Introduction Modern adaptive systems face the fact that the long-term consistency of their behavior is not guaranteed by simple error minimization. Classical controllers (PID, Kalman, EWMA, etc.) are able to maintain formal stabilization of signals, but do not ensure semantic or contextual consistency of operation. In other words, an algorithm may remain stable in the statistical sense, but produce fragmented, inconsistent behavior. This is due to the fact that traditional approaches do not take into account the structural effects of adaptation - the accumulation of internal changes that affect the very structure of the model. As a result of long operation of the system, small mismatches can accumulate and lead to a gradual drift of its parameters and states. The key reason for this phenomenon lies in the fact that classical approaches to adaptation operate with external time and instantaneous criteria, but have no notion of how long the system exists as the same coherent agent. They do not distinguish "fast response" and "long continuance". As a result, adaptation becomes a process without an internal tempo, without a sense of the duration of its own state. This is precisely where the need to introduce the concept of internal time arises. Within the framework of the Petronus project, a new control paradigm was proposed, aimed at preserving the coherence (consistency) of the system in the process of adaptation. Special architectures were developed, such as D^3A and

ΔE-CAS-T, introducing additional regulation layers for tracking meaning and structure in the behavior of algorithms. This article, published by the author in open access, constitutes a fixation of the priority of this original concept (prior art) and aims to formalize the concept of internal time as a key parameter determining the duration of the coherent state of an adaptive system. Methods of evaluation and internal interaction are not disclosed specifically due to the conditions of filing a provisional patent. Below, the prerequisites for the emergence of this idea, its implementation on the basis of the D^3A and ΔE-CAS-T architectures, as well as the consequences of ignoring internal time during prolonged adaptation, are considered.

Context and the problem of coherence Coherence in an adaptive system means internal consistency: correspondence between perception, reaction, and accumulated context. Classical learning and control algorithms aimed at minimizing instantaneous error often do not track this consistency. They may remain stable by the error criterion, but miss a gradual divergence between the model and reality. For example, a controller may statistically compensate disturbances, but over time small structural changes not reflected in the model accumulate. Such structural drift represents an irreversible shift of the internal parameters and states of the system associated with continuous adaptation. In the D^3A architecture, drift is formally defined as an accumulated measure of residual antisymmetric deformation (spin) associated with changes in internal operators or rules of adaptation. In essence, drift is the structural memory of the system about its own changes. It is important to emphasize that drift is neither noise nor a random error; it inevitably arises in any adapting system with incomplete dissipation. The problem is that without special control such drift undermines coherence over time. The system may remain workable on short intervals, but on long horizons the accumulated small discrepancies (for example, unaccounted internal stresses or unnoticed parameter shifts) lead to a loss of regime - a sudden deterioration of control quality or even going beyond stability boundaries. A different approach to adaptation is needed, where long-term structural consistency is placed at the forefront. This challenge is what motivates the introduction of the concept of internal time.

New architectures: D^3A and ΔE-CAS-T To maintain structural consistency, special architectural solutions were proposed. Directional-Deformation-Dissipation Architecture (D^3A) is a multi-level approach to adaptive control that explicitly models and regulates the relationship between the directionality of influence, the arising deformation of structure, and its dissipative suppression. The D^3A architecture combines four key components: (1) a directional constraint operator (W_{DC}, essentially an implementation of the principles of UTAM), which sets permissible directions of change of the system state; (2) an estimator of operational spin - the antisymmetric component of the gradient induced by directional influence; (3) an adaptive dissipative regulator (of the ΔE class), which suppresses residual deformation while not reducing the responsiveness of the system; (4) a metric of accumulated drift, measuring the total residual deformation (spin) over time. Taken together, these elements form a closed loop: directional influence $\rightarrow$ spin $\rightarrow$ dissipation $\rightarrow$ residual spin $\rightarrow$ drift, and the accumulated drift, when exceeding a threshold, can by a feedback signal influence the strengthening of constraints or dissipation. Thus, D^3A introduces into an adaptive system a new structural layer that tracks the direction and "twist" of changes, dissipates excessive deformation, and prevents small irreversible changes from accumulating without control. In fact, an operationalization of volitional constraint (UTAM) at the system level is realized: instead of an abstract "goal", concrete geometric frames of permissible trajectories are set, violation of which is considered structurally incorrect behavior, even if it reduces local error. D^3A ensures that adaptation occurs only within limits that do not destroy the integrity of the system. In parallel, the ΔE-CAS-T (Coherence Adaptive System with Thermostat) architecture was developed, aimed at maintaining coherence through multi-stage self-regulation. ΔE-CAS-T is a three-loop adaptive controller combining: (i) ΔE-Core - a behavioral fast-response loop that aligns the response with the input influence smoothly and without jerks; (ii) a coherence observer (Goodness/CCI) that evaluates the degree of consistency of current behavior with context and computes a coherence index; (iii) a coherent thermostat that regulates the internal "entropy" of the system (the degree of variability) based on signals from the observer. Unlike ordinary adaptive algorithms that may be accurate but lose attachment to context, the ΔE-CAS-T system introduces an internal regulation layer - a kind of synthetic conscience that ensures behavior remains consistent and meaningful. The three ΔE-CAS-T loops function jointly: the ΔE core smooths the response, minimizing the instantaneous mismatch of perception and reaction; the CCI layer turns this mismatch into an indicator of "goodness" (a coherence coefficient), and the thermostat adjusts the permissible level of variability of the system so as to maintain a balance between stability and adaptability. In more recent versions, an external observer (External Observer) has also been added, predicting changes in context (for example, a shift of the equilibrium position) for anticipatory correction - this reduces lag and prevents the accumulation of drift during abrupt changes in the environment. In essence, ΔE-CAS-T implements the principle of biological homeostatic feedback, but at the level of information: the system itself maintains a semantic balance between the accuracy of performing the task and preserving internal consistency. The D^3A and ΔE-CAS-T architectures laid the foundation for understanding how one can structurally guarantee stable adaptation. They introduce concepts necessary to describe internal time: constraints that prevent arbitrary wandering of the system; measures of internal "twisting" of dynamics (spin); adaptive dissipation that does not allow integrity to be violated; and coherence assessment that returns the system to a semantic balance. Building on these ideas, we now formalize internal time and its role.

Internal time as a measure of coherent context Internal time is not an abstract philosophical category. It arises as a consequence of quite concrete structural constraints of any adaptive system. Any system capable of change inevitably produces residual deformations. Any directed adaptation leaves a trace. In the D^3A architecture, this is formalized through the concept of operational spin and accumulated drift. Even with correct dissipation, part of the deformation is not eliminated completely and accumulates as the structural memory of the system about its own changes. This drift is not noise, an error, or an implementation defect. It is the price for long existence and adaptation. In this context, internal time can be defined as a characteristic interval during which the accumulated drift remains below a threshold that destroys the current coherent regime. While this threshold is not exceeded, the system preserves identity: its responses remain consistent with its past state, and causal links between action and result remain valid. When internal time expires, the system loses the ability to continue itself in its previous form. A regime transition occurs, which may look like sudden instability, degradation of quality, or the need to rebuild the model. It is important to emphasize that internal time does not coincide with external time. Two systems may operate equally long in hours and seconds, but have radically different lengths of internal time. One system may maintain coherence for millions of iterations, another may collapse after thousands of steps, even if both demonstrate similar accuracy indicators. The difference between them lies not in the speed of learning and not in the power of the model, but in the ability to hold context over time. At this stage, it is useful to turn to human experience, because it provides a rare case of direct access to the experience of internal time. A person is intuitively familiar with the fact that subjective time is not equal to objective time. Practices of attention, breathing, and meditation demonstrate this with extreme clarity. When attention is scattered, time "falls through": hours disappear, days fly by unnoticed, events do not bind into a continuous line. When attention is collected and stable, internal time stretches. The same external interval begins to be perceived as saturated and long. The proposed mental experiment with water is not a metaphor, but an accessible protocol for experiencing internal time. The reader is invited to pour a full mug of water and begin to drink it continuously, without taking the lips off the edge, as slowly as possible, without making pauses and without interrupting contact with the water. On the first attempts, this seems practically impossible. There arises internal resistance, a sense of the absurdity of the task, the desire to "finish as soon as possible". However, as it continues, a qualitative shift occurs: attention ceases to be directed at the goal "to drink the water" and begins to hold the process itself. At this moment, subjective time changes radically. Minutes stretch, the sense of duration grows, and it becomes obvious that one mug of water can be experienced as a very long, continuous context. People who practice such exercises are indeed able to hold this process for tens of minutes and more, without breaks, without tension, exclusively due to stable attention. From the point of view of this work, this is fundamentally important, because it demonstrates the following: internal time is determined not by the number of events, but by the ability to hold a coherent context without breaks. As soon as the context tears, internal time breaks. As soon as the context is held, internal time stretches regardless of the external chronometer. The same is true for adaptive systems. By the internal time of a system we will understand a characteristic segment of time (or a sequence of adaptation steps) during which the coherence of its internal state and context is preserved. It is important that this is not a fixed external time by the clock, but precisely an operational measure - how long a continuous coherent regime lasts before the structure of the system changes noticeably. Internal time is determined by three factors: structural stability, causal reliability, and the memory of the system. Structural stability means that small disturbances do not lead to an irreversible restructuring of dynamics; the system remains within its invariants (for example, UTAM constraints) and does not go beyond them. Causal reliability implies that the cause-effect relations embedded in the model remain valid over the interval under consideration - external conditions have not violated the assumptions on which adaptation is based, and the system correctly attributes effects to its actions. Memory reflects how much the system remembers and takes into account past states in current adaptation - i.e., whether it resets the context of previous decisions too early. These three aspects jointly determine the length of internal time: the longer the system can maintain its structure, trust its models, and integrate experience, the larger its internal time horizon of coherence. Quantitatively, internal time can be linked to the accumulation of drift. If we denote $D(t)$ as the metric of structural drift by time t, then internal time (T_{int}) is approximately the interval on which $D(t)$ remains below the critical threshold after which the system loses current coherence. In other words, (T_{int}) is the duration of a stable regime before accumulating drift begins to irreversibly affect behavior. If drift accumulates slowly, the system has long internal time; if each new change immediately introduces significant irreversible deformation, internal time is short. Thus, in D^3A terms, any system with nonzero adaptation and finite dissipation will produce nonzero drift. The question is only in the rate of its accumulation – that is what determines the boundaries of coherent context. Internal time, in essence, can be considered an indicator of the "capacity" of the system to integrate changes: a large (T_{int}) means that the system can remain itself for a long time (its identity is preserved), whereas a small (T_{int}) indicates rapid regime changes and short-lived contexts.

Drift and regime loss when internal time is shortened When a system's internal time expires or is sharply interrupted, characteristic undesirable effects occur. The first is accelerated accumulation of drift. If an adaptive system is forced to switch to a new context before the previous one has stabilized, residual inconsistencies do not have time to dissipate. They are carried into a new phase of operation in the form of accumulated drift. Structurally, this manifests as the preservation of residual spin (deformation) after the actions of the regulator: part of the "tensions" does not have time to decay and passes further. Such a process can be compared to an under-treated sick person: the system carries forward errors of the previous regime. As this process repeats, drift sums as an irreversible price for long existence and adaptation. The second effect is regime loss or loss of stability of the current behavior. Internal time is associated with the presence of a certain reserve of strength in the system: while the context is coherent, the system operates in some regime (attractor) with certain characteristics. If internal time is sharply interrupted (for example, due to a large disturbance or due to the accumulation of small drifts), the system falls out of this attractor. A sudden transition occurs - a regime restructuring. In D^3A terms, when the accumulated drift $D(t)$ exceeds some threshold D_{max}, switching is triggered: either constraints are tightened (the UTAM policy changes), or the dissipation coefficient is increased (ΔE intensively damps oscillations). Such a transition can be interpreted as the system's attempt to "catch" a new regime, since the old one has already become unstable. However, this transition is a sign that coherence has been interrupted: the previous context is no longer held. In practice, this may be expressed in stabilization failures (error spikes, unpredictable outliers in algorithm behavior) or the need to retune/recalibrate the model. Shortening internal time means that the system leaves too early the state where its adaptation was valid into a new state for which it is not ready. The third accompanying effect is stabilization failures. They occur because regulators tuned for the previous regime do not have time to restructure instantly. Coherence is violated, and over some interval control becomes ineffective or chaotic. This is precisely that "failure" when the system temporarily loses the ability for purposeful stabilization until a new coherent context is established. If internal time is very small (the context constantly tears), the system is in fact all the time in phase transitions and does not manage to stabilize at all. Thus, the interruption of internal time adversely affects the adaptive system: useful drift (slow evolutionary tuning) turns into harmful - accumulated and uncontrolled, regimes replace one another, and stability is not achieved.

Internal time as a regulator of drift Internal time can also be considered as a regulator determining the character of adaptation. A long internal time horizon acts like a buffer smoothing changes. When the system has sufficient "memory length", any directed disturbances dissipate gradually, localizing drift. An adaptive-dissipative mechanism (for example, a ΔE regulator) has time to absorb structural deformations on the spot and return the system to equilibrium, without allowing residual spin to spread far. Local fluctuations are averaged over a long interval, and cumulative drift over that interval remains small. In other words, if internal time is large, drift is effectively damped locally and does not have time to bring the system out of equilibrium. This corresponds to a low-frequency adaptation regime: the system is somewhat "inert" to fast shocks, but reliable over a long term. In the D^3A formalism, such a regime is equivalent to a large averaging window -

for example, computing variation and jerk over a long sliding window gives priority to stability and noise filtering. The system sacrifices instantaneous sensitivity for long-term stability. The opposite situation: shortening internal time makes the system more reactive, but at the price of structure. A short coherent context means that the system forgets the past very quickly and orients itself to the latest changes. Yes, this increases responsiveness - the adapter instantly reacts to fresh disturbances without averaging them with old data. However, in this case almost no time remains for dissipation of spin: each new disturbance is superimposed on effects of the previous one that have not yet fully dissipated. Drift under such conditions is not damped, but accumulates and immediately leads to regime switching. Short internal time turns drift into a trigger of regime transitions: the slightest mismatch is immediately detected as the need to change strategy. As a result, the system may rush between states (regimes) without achieving long-term coherence in any of them. Such a picture is observed, for example, in retuned controllers without proper filtering: if the adaptation parameter is updated too aggressively, the controller will over-regulate - in fact, each noise spike will be treated as a signal for a large correction, and the system will lose a stable regime. Therefore, internal time acts as a parameter regulating the balance between stability and responsiveness of adaptation. With long internal time, drift is "kept on a leash" and does not threaten integrity - the system tends to remain in the current regime and only softly correct it. With short internal time, drift effectively controls the system, constantly transferring it into new regimes. It should be noted that the optimal choice of internal time depends on tasks and conditions: too large T_{int} may lead to inertia (the system will ignore even important changes), and too small may lead to chaotic switching of states. Architectures like ΔE-CAS-T effectively attempt to dynamically regulate effective internal time - through the inertia parameters μ_t , damping D_t, and center prediction c_t, the system adapts its memory to current conditions so that drift does not become uncontrolled. Thus a compromise is achieved: local drift is damped, and when signs of instability accumulate the system adjusts the structure in advance (strengthens centering, increases dissipation), prolonging the coherence of the regime.

Conditions of a coherent regime

From the above, conditions necessary for stable existence of a system in a coherent regime for a long time (that is, with large internal time) can be derived. First, accumulated drift must remain bounded. Formally, there exists a threshold D_{max} that the drift metric does not reach: $D(t) < D_{max}$ for all t within the considered regime. A practical criterion is the absence of triggering of emergency switches: if neither the limiter nor the dissipator has reached saturation, the regime can be considered preserved. In the D^3A architecture, this condition is explicitly defined: while $D_t < D_{max}$, no structural correction occurs. The

second condition is sufficient dissipative capacity of the adapter. A ΔE-class regulator must have time to smooth most of the arising deformations. Ideally, the system operates in a controlled dissipation regime, when any directed impulses dissipate before becoming destructive. If the adaptive loop is capable of suppressing anti-coherent components (spin) proportional to their magnitude and variability, then drift remains small and controllable. The third is compliance with structural constraints (invariants). The system must not be forced to go beyond the boundaries established by the initial assumptions (be it physical constraints or UTAM rules). If an external influence or internal optimization tries to lead the system along a trajectory that violates basic invariants of identity or safety, coherence inevitably collapses. Therefore, for a stable regime it is necessary that the admissible set of states and trajectories remain continuous and non-contradictory over time. Simply put, the environment must not require from the system what it is not designed for - then internal consistency is preserved. Finally, the fourth condition is correspondence of internal time to the scale of external changes. If the characteristic time of change of the external environment (or task) significantly exceeds the internal time of the system, then the latter manages to adapt without breaking coherence. For example, if the environment changes slowly, the system can hold a long coherent context and smoothly adjust. But if the environment throws challenges requiring a reaction faster than the duration of internal time, then even all else equal coherence will be violated - the system will have to "jump" after changes. Thus, for stable coherence a certain inequality of time scales is necessary: the system's T_{int} must be sufficient to absorb key changes of the external dynamics. Summarizing, a coherent regime is possible for a long time if:
(a) the system has mechanisms of constraint and dissipation that keep drift below a threshold ($D_t << D_{max}$);
(b) adaptive parameters are tuned so that precisely destructive components of deformations are suppressed while preserving sensitivity (a regime of controlled entropy in ΔE);
(c) structural constraints (UTAM-like) are not violated by external or internal factors;
(d) the internal memory horizon is not less than what is required to average and track the current context of the environment.
Fulfillment of all these conditions ensures maximum duration of coherent behavior - that is, a large reserve of internal time. Otherwise, the system will sooner or later transition into another regime or degrade. Now the key postulate which this work fixes and on which it insists: Understanding internal time as a measure of the existence of context and the progression of continuance, based on stability and memory, leads to the realization of its fundamental role in regulating drift and stabilization of adaptive systems. This postulate is not a conclusion at the end of reasoning. It is the starting point through which all other elements - drift, dissipation, constraints, observer - acquire strict meaning. Drift is dangerous not in itself, but because it shortens internal time. Dissipation is important not as error smoothing, but as a mechanism for prolonging coherent context. The CCI observer

is necessary not for quality assessment, but for fixing the moment when continuation becomes impossible.

Comparison with classical models The proposed approach fundamentally differs from traditional adaptation schemes focused on eliminating statistical discrepancies (such as problems of sim2real transfer or model mismatch). In classical tasks of transferring a model from simulation to the real world, the main attention is paid to differences of data distributions, calibration of parameters, compensation of noise and inaccuracies - in other words, statistical incompatibilities. It is considered that if the model is sufficiently generalized or its parameters are corrected, it will work in new conditions. However, with such an approach the long-term structural dynamics of the system are missed. A model ideally trained on data may still, over time, lose adequacy if unpredictable drift accumulates in real operation. Classical controllers and learning algorithms do not track metrics such as structural drift or context coherence - they rely only on current error or reward. As a result, situations are possible where the system maintains formal stability, but its actions gradually cease to correspond to the original intent. In Petronus reports it was noted that standard controllers may remain statistically stable, but at the same time generate fragmented, incoherent behavior lacking semantic integrity. This is precisely a manifestation of structural incompatibility: the model by indicators like MSE or reward may be "fine", but from the point of view of maintaining the identity of the system - no. By introducing the concept of internal time, we explicitly focus on the structural consistency of adaptation. The proposed parameter cannot be reduced to the variance of error or the spread of model parameters - it is a new axis of analysis absent in classical methods. For example, in sim2real tasks it is usually proposed to improve the simulator, bring the distribution of sensor signals closer to the real one, add domain randomization, etc. All this is important, but even when statistics coincide the real system remains open in time: it works continuously, whereas learning proceeded in episodes. If this moment is not taken into account, a model ideally transferred by statistics will on a long time interval begin to drift and may arrive at a state not encountered either in simulation or in training data. Faced with this, the usual approach is forced either to constantly continue training the model, or periodically reset the system. The concept of internal time offers another perspective: to prevent such drift from the outset by embedding into the algorithm an understanding of its "age" and structural state. Thus, the difference from classical model mismatch can be expressed as follows: instead of fitting to the statistics of the environment, the system is fitted to its structural requirements - rates of change, permissible directions of evolution, the need to preserve the integrity of behavior. In a certain sense, internal time is a parameter that makes an adaptive system more like a living one: it remembers who it was a second, a minute, an hour ago, and will not allow itself to become a completely different "being" without a corresponding transition phase.

Classical algorithms lack this layer of self-control, therefore they can very quickly lose the course without even "understanding" that they have lost the original task from view. In our approach, it is proposed to track coherence as a first-class quantity, on a par with error. This approach is original and structurally irreducible to existing control models - it adds a new measure (internal time) and a new success criterion (preservation of coherence) that are not present in standard adaptation theories.

Conclusion Internal time is a new operational parameter of an adaptive system characterizing the duration of its coherent existence. By introducing this parameter, we translate the intuitive concept of "preserving identity over time" into the language of engineering criteria. The analysis performed on the basis of the D^3A and ΔE-CAS-T architectures shows that accounting for internal time is of decisive importance for long-term stability: without it, small structural distortions inevitably accumulate (each adaptation leaves a trace), and sooner or later the system will face drift and regime loss. Any adaptive system either possesses internal time, or inevitably destroys itself during long operation. Internal time is not added on top of the system; it arises from the structure of its self-regulation. Conscious introduction of this parameter into the control architecture makes it possible to move from short-term optimization to genuine continuance. A system possessing internal time is capable of changing without losing itself. A system deprived of it sooner or later loses coherence, even if for a long time it does not notice it. It can be stated that any adaptive system with incomplete suppression of deformations has nonzero drift. Consequently, without a special mechanism controlling its growing influence it is impossible to guarantee preservation of consistency of behavior over large time intervals. The concept of internal time offers such a mechanism: it establishes how long a system can adapt while remaining itself, and thereby sets a boundary beyond which either structural correction or a context reset is required. From an engineering point of view, implementing internal time metrics and related limiters means a transition to coherence-oriented design of algorithms. This is a new level of priority complementing classical optimization goals. The approach described in the work is fixed by the author as an open publication (prior art), emphasizing the inventiveness and structural novelty of the idea. The implementation itself is presented in the patent documentation. We hope that further research and experiments will develop the provisions proposed here. Control of internal time can become the missing link that will ensure reliable operation of adaptive systems on ultra-long horizons - where today they inevitably face loss of coherence without external retuning. Possessing a "sense of time", a system will be able to learn and change without losing itself.

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