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THE INTERTWINED NATURE OF SIMPLICITY AND COMPLEXITY: A NEW PARADIGM FOR UNDERSTANDING COMPLEX ADAPTIVE / AUTONOMOUS / LIVING SELF-IMPROVING SMART SYSTEMS

Prokopchuk Yurii [ORCID]

Institute of Technical Mechanics of the NASU and the SSA of Ukraine,

doct. of tech. sc., assoc. Prof, Ukraine

Abstract. *Research in the field of autonomous systems focuses on developing machines, robots, and systems capable of autonomous learning, perceiving their environment, and interacting with it like a living being. For autonomous systems, flexibility in the face of limited resources and radical uncertainty is critical, and system failures are unacceptable. The key research question: How is the balance between complexity and simplicity achieved in cognitive systems? Resource economy leads to criticality - a self-organizing balance between simplicity/parsimony and complexity. In terms of the evolutionary self-improvement of (natural) smart systems, the 'System 0/1/2/3' architecture has been substantiated. The limit generalizations paradigm offers a holistic approach to the complexity-simplicity trade-off.*

Keywords: *Cognitive Platform Engineering, Architecture of Thinking, Complexity Control, Sketching, Limit Generalization Paradigm - LGP, System 0/1/2/3, Living Structure, Ultra-Low-Power Intelligence, Self-improvising / Self-expanding Memory, Self-Transcendence, LGP-Principle of Superefficiency, Systems Thinking*

Introduction. Research in the field of autonomous cognitive artificial systems (CAS) focuses on developing machines, robots, and systems capable of autonomous learning, perceiving their environment, and interacting with it like a living being. For CAS, flexibility under resource constraints and radical uncertainty is crucial, and system failures are unacceptable. The key research question: How is the balance between complexity and simplicity achieved in cognitive systems? The limit generalizations paradigm (LGP) offers a holistic approach to the complexity-simplicity trade-off in building cognitive models and architectures, including the analysis of unconstrained self-improvement in autonomous intelligent systems or CAS [1], [2], [3]. At the core of the simplification / generalization mechanism lies the demand for resource efficiency (working memory, energy for thought and action), faster reaction and discrimination times, and the broadening of possibility spaces for

patterns. To effectively 'simplify, economize, and survive,' a system must provide, firstly, ultra-redundancy in the choice space; secondly, a natural (implicit) mechanism for selecting the best solutions; and thirdly, the embodiment of efficient patterns, guided by the laws and constraints of Nature and Society [1].

According to LGP, the primary task of human-level intelligence is the realization of its desires, needs, and fantasies amidst the struggle for existence, fierce competition for resources, and the necessity to demonstrate compliance with certain social norms to external observers. Intelligence is the engine of Reason/Mind. The primary criterion for the quality of intelligence is the balance between 'needs', 'safety', 'economy', and 'pleasure', with an emphasis on 'intrinsic motivation'. A key aspect of 'pleasure' is the 'instinct for cognition / novelty.' 'Safety' encompasses ethics. Resource economy leads to 'criticality' - a self-organizing balance between 'simplicity/parsimony' and 'complexity', as well as 'eigenbehavior', 'asymptotic rationality', 'pattern entanglement', and outsourcing [1], [4]. The pursuit of an overall balance can result in 'wisdom' and 'dark solutions' (the realization of fantasies). 'Wisdom' involves a comprehensive assessment of long-term risks to life and functioning. 'Safety' and 'economy/parsimony' lead to 'radical reduction' - the ability to extract only 'control information,' operate with meanings, 'controlled hallucination,' language, and intuition (the metaphor being 'consciousness'; System 0/1/2/3) [1], [2]. The necessity of survival leads to agency, self-transcendence, or self-overcoming - a creative expansion of pattern possibility spaces. An agentic process compresses/generalizes, predicts, and acts [5]. The foundation of spirituality lies in lived experience, the extended Mind, and Culture.

Some of the complex and relevant applied research questions are: ‘AI Epistemology for rigorous scientific foundations’; ‘Aligning generalization between humans and machines [6] (a crucial yet often overlooked aspect is the different ways in which humans and machines generalize).’ For example, LLM reasoning about language is fundamentally different from that of humans. The underlying mechanisms of LLM-models limit their capacities for meaning and naturalistic interaction. Humans are capable of synthesizing experience, literally constructing it within their imagination. Furthermore, the brain is unable to differentiate between

'actual' and imagined experience. The more vivid the imagination, the greater the number of new ideas generated. One can agree with the central argument of the work [7]: “effective AI development requires embracing rather than obscuring the fundamental differences between artificial and human intelligence.” The key factor in human behavior is "unsatisfied desires." Evolution greatly limits the scope of potential design principles. This results in interdisciplinary challenges across AI and cognitive science that must be tackled to support effective and cognitively supported alignment in human–AI teaming scenarios.

Core Results. A crucial role in understanding the ‘simplicity-complexity’ problem is played by the following proposition by Gregory Chaitin (one of the founders of algorithmic information theory): ‘A model is better if it can explain more with less.’ According to ‘Occam's razor,’ given two theories explaining certain data, the simpler one should be preferred. In other words, a useful theory provides information reduction/abstraction: the comprehension of data compresses it into concise descriptions/sketches. Implications: ‘simplification’ and ‘criticality’ are interconnected; optimal complexity - the ‘edge of chaos.’ Criticality acts as one of the fundamental natural mechanisms of the universal creative process - the pursuit of beauty and excellence. Beauty guides us toward the possibility of creating the unprecedented (Self-Transcendence). Criticality is at the core of ultra-low-power (edge) intelligence.

Let’s examine certain aspects of ‘complexity’ and ‘simplicity / economy / cognitive load reduction’ from the perspective of cognitive self-improving systems.

Cognitive Complexity: all natural laws are in effect - multi-physics, multi-formalism, extended complementarity, quantum-like and fractal-like properties, multi-scalability, wholeness, multi-unity, ‘subjective inflation’; ‘social entanglement’; physics/phenomenology of the Mind - two singularities ('subjective reality' and 'consciousness'), ‘living structures,’ qualia; meaning as wholeness experienced; internal competition ('a thousand brains'), free will; fantasies, the struggle of contradictions - ‘dark decisions,’ ‘instincts/ethics,’ ‘dark personality factors,’ ‘freedom of the Mind’; internal tension, intrinsic motivation, inner world; speed-accuracy tradeoff; radical reduction of uncertainty or 'act of understanding /

awareness / mindfulness / insight / consciousness,' 'Language of thought,' 'Syntax without Language'; spirituality, religion; self-transcendence in the construction of situational spaces of possibilities (for patterns/actions); ‘body intelligence,’ ‘living/lived experience’ - triadic Events =<sketch, context, emotions> (triadic entanglement patterns; ‘Behind every thought is an emotion’); phenomenology of temporal experience: hierarchical / holarchic model of multiple timescales.

Dynamic phenomenology of conscious occurrent thinking: Current events are a live experience of interacting with the environment in the here and now: the momentary experience of feeling oneself identified with that which one thinks. This phenomenal quality is a distinctive feature of thinking experience. This quality is based on a ‘continuum of discrimination/distinction tasks (CDT)’ associated with the current event [1]. CDT is a core System 0 process that relies on the strong connectivity (generalized entanglement) of the ‘body-brain-mind-environment/society system’ / mental sphere (quantum-like models). The stream of thoughts emerging during a CDT task gives rise to a 'Thought Flow Network – TFN'. All TFNs become part of the ‘Space of Thought Flows - STF’. As a crucial component of lived experience, STF trains individuals/agents to recognize and correct inefficient thinking habits (Asymptotic Rationality). This is the essence of the phrase: 'Meaning is an experience of wholeness based on lived experience' (arising from the agent's psychophysical interaction with the environment).

It is posited that any natural discrimination pattern is grounded in a stochastic ‘Creative Stirring / Mixing Layer’ that operates on the basis of a heuristic space (Spontaneous Thought Processes; Heuristic-driven stochastic search: heuristics are actions). Cascading instability mixes the mind's resources across spatio-temporal scales (self-similar topologies; stochastic self-similarity; weak control hierarchies). This implies that 'Creative Stirring' is not merely random noise, but a dynamic process that iterates through or activates 'smart heuristics' within System 0, preceding the collapse of the decision wave function in System 1. Nature inherently encompasses instability, chaos, and quantum-likeness as essential elements.

The stream of thoughts during the process of solving coupled discrimination tasks generates a vast number of values for **causal interpretive variables** $\{\underline{z}/Z_v\}$

(where V represents heuristics), reflecting the essence of phenomenal experience alongside sketch networks (or **proto-qualia**). Metaphor: {V} - mental 'glue' – interaction carriers: they act as ‘exchange particles’ or ‘messenger particles,’ allowing images to influence one another’s behavior and properties. Interaction carriers link sketches within and across sketch networks.

Within the System 0 CDT framework, the processes of solving discrimination tasks can coexist in a state of superposition, leading to spontaneous insight as they merge into a conscious solution (System 1). In other words, the transition from subconsciousness (a manifold of possibilities) to conscious thought (a definite choice) may involve quantum-like decoherence, where quantum-like states collapse into classical outcomes (System 1: collapse of the decision wave function). LGP substantiates the use of a specific class of quantum-like measurements (modeling “Mental Entanglement”).

The CDT mechanism fully aligns with Gregory Bateson's concept of information as ‘a difference which makes a difference.’ Specifically, each resolved task within the ‘continuum’ creates a difference that helps solve the initial Z-task. The verb ‘makes’ emphasizes the process of transforming one set of differences into another within cybernetic and biological systems. Detecting differences is the most fundamental act, demonstrating that information is the bedrock of sense-making for an organism, enabling any degree of complexity in its interpretative capabilities.

From the perspective of enactivity/LGP, cognition does not simply exist ‘inside our heads’; it is like an improvised dance unfolding in the moment as the organism interacts with the world (Architecture of Autonomy: CDT framework - a naturalistic framework for Free Will).

Compression through Sketching (Complexity Control): The brain does not store details; instead, it creates efficient abstractions (sketches). This allows for the transmission of information's essence via inter-network connections without overloading ‘intra-network dynamics’ channels. Sketching significantly expands the action-possibility spaces.

Complexity of Simplexity: criticality – ‘critical sketches’, ‘thin slices’ of heuristics – fast and frugal heuristics; metaphors – ‘post-critical sketches’ (sketches

overlap for different images); fantasies – ‘art-sketches’; reduction – extraction of meaning/essence (construction / activation of a sketch network), governing information; embodiment – functional systems, radicals; semiosis, signification, symbol grounding – COGs (COgnitive Groups - sketch-sign couplings - ‘Grounding Act’; ‘every point/sign of mental space unfolds into a structure/infinity’), cognitive transition – energetic decoupling of COGs, emergence of language and System 2; communication based on meaning (the message/text is grounded in the subjects' ‘mental entities/gestalts/COGs’; overlaying narrative structure on information / imagery / gestalts), outsourcing of knowledge and actions; ‘controlled hallucination’, Interface Theory of Perception (based on LGP); ‘eigenbehavior.’

Fragment of LGP-Epistemoverse: Unifying Principles of Generalization - spiritual networks of sketches – ‘Living Structure’ (holarchy); networks for distinction tasks, networks of causal interpretive variables, signaling networks, computational proto-qualia; the mental sphere or the ‘network of spiritual networks of sketches’; Thought-action (Chains-of-Thought-and-Action), the ‘arrow of time’ (an event sequence conditioned by thought-action); Living/Lived Experience: Subjective Space-Time-Language-Intentions/Action – SSTLA (the totality of local ‘arrows of time’); ‘Linguistic Bodies’: Overlaying Narrative Structure on Information, Story/Scene Comprehension; Orchestration Layer: Networks of Control Mechanisms; Intrinsically Motivated Behaviors: ‘Dark Decisions’, Hidden / Secret motive.

In the LGP-Epistemoverse, time is not unitary; it is engendered by an entangled multitude of local acts of thought-action (SSTLA: Scaling of Complexity, Effective Agency Emerges: evolving higher level goal-directed activity and agency).

Asymptotic Rationality - decisions are based on asymptotic/critical sketches and lived experience: maximum expansion of action-possibility spaces; maximum speed of discrimination task performance; maximum flexibility and maximum reduction of cognitive/resource load; maximum tolerance for ambiguity/uncertainty; maximum knowledge transfer to situational nuances (far transfer of learning); maximum risk / reward / consequences assessment over extended time horizons (based on experience); wise decisions.

The System 0/1/2/3 iceberg metaphor: System 0 represents the ‘submerged part of the iceberg,’ where the setting and solving of discrimination tasks remain subconscious (quantum-like non-locality, superposition, and entanglement). System 1 is the ‘waterline,’ where the CDT solution becomes conscious (quantum-like decoherence in decision-making: collapse of the decision wave function). System 2 (sequential logical thinking) and System 3 (symbiotic thinking) constitute the ‘visible part of the iceberg.’

How it works in LGP-logic: System 0 is not a data ‘warehouse,’ but a seething ocean of potentials. ‘Creative Stirring’ is the turbulence mechanism that prevents the system from stagnating, constantly ‘lifting from the depths’ (the heuristic space) various alternatives. Heuristics act as filters or ‘smart shortcuts’ that structure this chaos, channeling it toward the point of assembly. System 1 is the moment when a specific sketch crystallizes (decoheres) from this ‘boiling’ state. This LGP-logic explains why System 0 is the source of superefficiency: it does not iterate through options sequentially; instead, it 'simmers' them within a field of heuristic-actions, surfacing a ready-made result.

In contrast to classical models where the brain is a computer, in LGP-logic, the brain (System 0) is a ‘reactor’. Superefficiency is achieved because 'stirring' occurs instantaneously and across the entire volume of the heuristic field, bypassing the time-consuming constraints of linear computation.

The ‘Sketch’ Concept: As the primary, dynamic cognitive unit emerging within System 0, the ‘Sketch’ establishes the role of a living, plastic foundation of thought - directly opposing the rigid ‘data’ of the computational metaphor. Primordiality: The Sketch is a pre-verbal and pre-logical level of ‘proto-meaning,’ which enables rapid discrimination before any formal processing occurs. This definition elucidates the origin of speed and superefficiency within the LGP-model: the system does not process 'bits' of information; instead, it operates with 'proto-meanings'.

LGP provides an answer to Hawking’s fundamental question: 'What is it that breathes fire into the equations <…>?' (Stephen Hawking, A Brief History of Time).

The 'Soul' Metaphor | The 'Fire' Metaphor: Spiritual Networks of Sketches, Experienceable Forms, Living Smart/Cog-Structure. 'The fire in the equations' is that very substance or dynamic force that animates static mathematical structures, transforming them into reality. The metaphor of mental 'fire' refers to the stochastic turbulence of System 0/1, which 'brews' potentials and converts abstract heuristics into living action/being. LGP posits that 'subjective reality' (or Mind) is a dynamic process of 'enlivening' 'living structures' through a network of spiritual networks of sketches, SSTLA, permanent 'continua of discrimination tasks', 'living experience', 'unsatisfied desires', infinite acts of meaning-generation, cascading instability, and proto-meanings. From these proto-meanings, qualia (pure experience) crystallizes (Qualia as a Universal Principle) [4], [5].

Complexity Synchronization of Sketch Networks: This science motif is based on the scaling in sketch networks and the need for a network of sketch networks to exchange information internally during intra-network dynamics and externally during inter-network dynamics. At the core of this synchronization lies the generalized entanglement of the mental sphere (integrity is ensured by high entanglement within a network-of-networks). **Resonance instead of computation**: When complexity is highly synchronized, information is transmitted through an instantaneous system-wide response rather than step-by-step processing. This conserves resources: the brain 'recognizes' rather than 'computes' (meaning as wholeness experienced).

LGP-Principle of Superefficiency in intelligent self-improving systems (Principles entailed by Complexity). LGP introduces the principle of cognitive superefficiency, which posits that the internal state of a cognitive system self-organizes toward a critical regime. In this state, optimal efficiency in discrimination tasks is achieved, encompassing resource and risk management, specifically: maximum adaptability, flexibility, predictivity, embodiment, stealth, and speed of consensus-based decision-making (informed by experience/templates). This is coupled with economy and deep auditing, ensuring fault tolerance and antifragility. Embodiment allows for deep outsourcing. Economy enables the construction of a

‘niche,’ ‘nudging’ methods, ‘soft power,’ and ‘non-coercive control.’ The implementation of the LGP-principle of superefficiency leads to ‘wisdom.’

Conclusions. LGP explicitly models how meaning, interpretation, and analogy emerge from interactions among layered representations, forming a coherent framework capable not only of modeling minds but also of serving as a blueprint for building them. LGP offers a structural foundation upon which multiple ways of understanding the mind may be reconstructed. Fractal-like calculus facilitates rethinking ‘Hard Problems.’

Systems 0/1/2/3 are the essence of human evolutionary self-improvement. The LGP integrates concepts from complexity theory, chaos theory, quantum-like science, dynamic systems theory with psychological models of cognitive processing, suggesting promising directions for developing more adaptive and psychologically plausible AI systems. Theoretical implications point toward a new generation of artificial cognitive systems that better approximate the fluidity and adaptability of human cognition and thinking. Under the ‘pressure of complexity,’ advanced AI allows to overcome the fundamental limitations of the ‘logic of living systems.’ Systems thinking helps each agent / person manage different perspectives to bring them together in the best possible way.

We argue that if symbiotic systems (the agent's intellectual web; System 3) can achieve functional capacities exceeding purely synthetic systems - by integrating uniquely human qualities such as intuition, vivid imagination, strategizing, lived experience, inner world, free will, self-improvising memory, self-transcendence, wisdom, operating with meanings, and embodied meaning-making - the incentive landscape for AI development may shift fundamentally toward partnership optimization rather than human replacement. LGP proposes a mathematical formalization of Symbiotic Super-Intelligence as an emergent property of synchronized human-AI interaction.

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ВЗАЄМОЗВ'ЯЗОК ПРОСТОТИ ТА СКЛАДНОСТІ: НОВА ПАРАДИГМА РОЗУМІННЯ СКЛАДНИХ АДАПТИВНИХ / АВТОНОМНИХ / ЖИВИХ ІНТЕЛЕКТУАЛЬНИХ СИСТЕМ, ЩО САМОВДОСКОНАЛЮЮТЬСЯ

Юрій Прокопчук

Анотація. *Дослідження в галузі автономних систем зосереджені на розробці машин, роботів та систем, здатних до автономного навчання, сприйняття навколишнього середовища та взаємодії з нею подібно до живих істот. Для автономних систем критично важлива гнучкість за умов обмежених ресурсів і радикальної невизначеності, а збої системи неприпустимі. Ключове питання дослідження: як досягається баланс між складністю і простотою в когнітивних системах? Необхідність економії ресурсів призводить до критичності – балансу між простотою і складністю, що виникає спонтанно. З погляду еволюційного самовдосконалення (природних) інтелектуальних систем було обґрунтовано архітектуру 'Система 0/1/2/3'. Парадигма граничних узагальнень пропонує цілісний підхід до пошуку / виникнення компромісу між складністю та простотою.*

Ключові слова: *проектування когнітивних платформ, архітектура мислення, управління складністю, ескізування, парадигма граничного узагальнення, Система 0/1/2/3, жива структура, наднизькоспоживаючий інтелект, пам'ять, що самовдосконалюється, LGP-принцип надефективності, системне мислення*