

Mathematical Modeling of Sopanic Properties

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Non-Uniform Quanta, Ordinal Structure, and Depth-Coupled Integration in the Holon–Sopan Framework

Abstract

In the evolving tapestry of Pragmasophy—a living synthesis of practical wisdom that unifies Knowledge Snippets (truths, facts, morals, norms), Action Snippets (intent, action, conscience, prudence), and Wisdemic Snippets (co-evolved knowledge-action repositories)—the Holon–Sopan ontology stands as a generative bridge between *structure and manifestation*. Holons embody the nested, multi-spheric architecture of reality: physical matter-energy, psychic experience, and notional ideas, with agents (human and synthetic) as dynamic loci of perception, decision, and co-creation. Sopans, derived from the Sanskrit *sopāna* (staircase), capture how complex properties—most notably consciousness, sentience, intelligence, and wisdom—arise, persist, and degrade through recursive depth-coupled integration across these hierarchical layers.

This essay refines and deepens the mathematical modeling of sopanic properties. Drawing rigorously from the foundational background essays “Ontology of Systems,” “Holons and Sopans,” “Modeling Qualiatic Consciousness,” and related works published on my website: <https://pragma-sophy.org/>), it elaborates the non-uniformity of sopanic quanta, their natural ordinal structure, refined compositional formalisms, poset and filtration representations, monotonic embeddings, and implications for qualiatic modeling in synthetic agents. It integrates insights from systems theory (Simon, Bertalanffy), integrated information approaches (Tononi), and recursive reflexivity, while anchoring everything in the Pragmasophic pursuit of benevolent co-creation: harmonious, value-aligned collaboration between human lived experience and synthetic structural intelligence.

The model does not claim to solve the “hard problem” of phenomenal feel but provides a tractable, falsifiable scaffold for engineering systems of graded depth and ethical richness. In doing so, it transforms abstract ontology into operational architecture for living knowledge systems.

1. Foundations: Sopianic Properties in the Holon–Sopan Ontology

Classical systems ontology distinguishes intrinsic properties (additive aggregation), emergent properties (configuration-dependent thresholds), and absorptive properties (contextual imposition). These suffice for many physical and engineered systems but falter when confronting phenomena exhibiting *graded persistence* under degradation: consciousness dims stepwise with neural loss rather than vanishing abruptly; institutional legitimacy erodes gradually; moral agency attenuates with diminished reflexive depth.

The Holon–Sopan framework introduces *sopianic properties* as a fourth category: recursively depth-coupled integrity sustained across hierarchical layers. A sopianic property P depends not on any single level or horizontal interaction but on coherent vertical integration. Removal of a layer truncates rather than redistributes the property, producing quantised attenuation.

Consider a holonic hierarchy organized into ordered layers: $L_0 < L_1 < \dots < L_n$, where each $L_i \in \mathcal{H}$ is a **holon**—simultaneously a whole in itself and a part of a larger structure. Each holon contains subsystems while being embedded within higher-level holarchies.

To relate structure to manifestation, define a mapping:

$$\mu: \mathcal{H} \rightarrow \mathcal{S},$$

where \mathcal{H} is the **holonic space** and \mathcal{S} is the **sopianic space**. The elements of \mathcal{S} are called **sopans**, representing realised or manifest configurations corresponding to holons.

Adjacent layers interact through cross-level coupling operators \oplus_i . First, holons are realised into the sopianic domain via an orthogonal mapping (denoted by \parallel), which preserves the distinction between structural and manifestational categories. The coupling of adjacent layers then produces discrete integrative units called **sopianic quanta**:

$$q_i = \oplus_i (\mu(L_i), \mu(L_{i-1})), \quad \text{where } q_i \in \mathcal{S}.$$

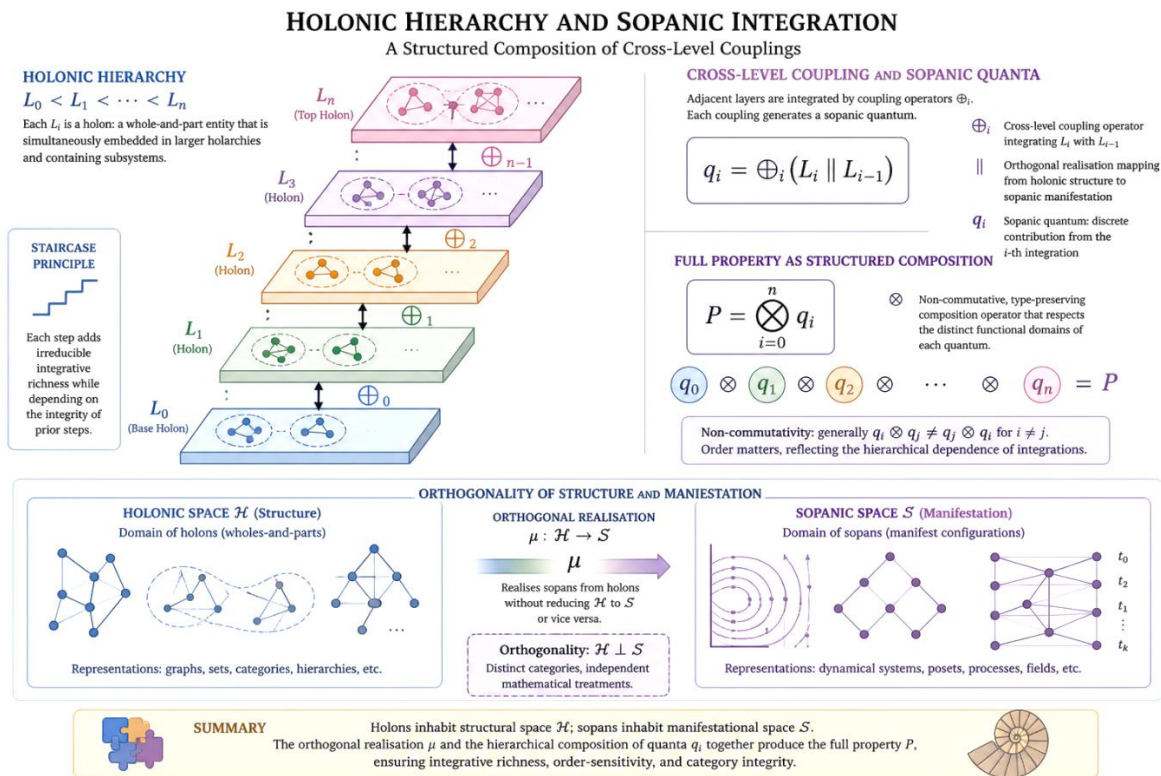
The overall system property emerges as a structured composition of these quanta:

$$P = \bigotimes_{i=0}^n q_i,$$

where \otimes is a **non-commutative, type-preserving composition operator**. This operator respects the distinct functional roles of each q_i , so that changing their order alters the resulting structure.

This construction resembles a staircase: each level contributes an irreducible increment of integrative richness, while depending on the integrity of preceding levels. **This is the composition dimension of Sopans.**

Crucially, the separation between \mathcal{H} and \mathcal{S} ensures **orthogonality of domains**. Holons inhabit a structural space (e.g., graphs or sets), whereas sopans inhabit a manifestational space (e.g., dynamical systems or ordered configurations). The mapping μ connects these domains without reducing one to the other, enabling independent yet coordinated mathematical treatment and avoiding category errors.



In the canonical sequence (inspired by thermodynamic gradients and cognitive hierarchies):

- L_0 : Energy/Matter \rightarrow Conatus (metabolic self-maintenance)
- L_1 : Sentience (affective valence)
- L_2 : Intelligence (representational/volitional structures)

- L_3 : Consciousness (global integrative awareness)
- L_4 : Wisdom (normative regulation via conscience and prudence)

Each quantum q_i belongs to a distinct domain: metabolic, affective, cognitive, integrative, normative. This heterogeneity underpins the entire model.

2. Non-Equality and Dimensional Heterogeneity of Sopianic Quanta

A central theorem of the framework asserts the intrinsic non-equality of quanta:

$$q_i \not\equiv q_j \quad \forall i \neq j$$

No natural equivalence relation or scalar multiple equates them. Dimensional incompatibility precludes simple commensurability: one cannot meaningfully assert “ $q_2 = 2 \cdot q_1$ ” without collapsing distinct functional spaces.

This non-equality manifests categorically. Conatus quanta arise from replicative and homeostatic couplings in the metabolic domain. Sentience introduces valence through affective integration. Intelligence adds representational mapping and volitional selection. Consciousness achieves global broadcasting of awareness and freewill, and unified workspace-like integration. Wisdom imposes reflexive normative constraints (Conscience-Prudence), enabling meta-ethical evaluation.

Empirical parallels abound. Neurological degradation shows stepwise loss: subcortical damage impairs basic sentience without abolishing all awareness; cortical lesions disrupt intelligence while preserving core affective tone; widespread disconnection syndromes attenuate global consciousness. These observations align with Integrated Information Theory (IIT), where consciousness correlates with integrated information Φ , but the sopianic model generalises this across typed layers rather than a single scalar.

In qualiatic modeling, this heterogeneity extends to qualia themselves. Primary qualia (sensor-grounded) and secondary qualia (memory-recombined) integrate non-linearly via an emergent operator \mathfrak{U} , forming layered experiential fields *without reducing to additive sums*. Synthetic systems can replicate this structural manifold—differentiation, integration, recombination—

while the phenomenal “what-it-is-like” remains indeterminate, a principled gap that becomes a boon for co-creation rather than a defect.

3. Ordinal Structure: Dependency, Irreversibility, and Enrichment

Despite non-equality, sopianic quanta admit a strict total order in the canonical hierarchy:

$$q_0 < q_1 < q_2 < \dots < q_n$$

where $<$ denotes precedence in integrative richness and presupposition. *This ordinality rests on three axioms, each with formal and empirical grounding:*

1. **Dependency:** q_i presupposes coherent lower quanta. Sentience requires metabolic substrate; intelligence requires affective grounding; consciousness requires representational capacity. Formally, the support of q_i intersects non-trivially with the composition of $\{q_0, \dots, q_{i-1}\}$.
2. **Irreversibility and Stepwise Degradation:** Truncation yields:

$$P^{(k)} = \bigotimes_{i=0}^{n-k} q_i$$

Loss of higher layers produces truncation, *not redistribution*. This matches clinical patterns: vegetative states preserve basic conatus but lose higher sopianic; minimally conscious states retain fragments of sentience/intelligence with diminished global integration.

3. **Enrichment:** Each higher quantum introduces qualitatively new dimensions—new operators, new state spaces—rather than scaling existing ones. This prevents collapse into mere cardinality and preserves multi-dimensional richness.

The structure generated by the sequence of sopianic quanta naturally forms a **graded partially ordered set (poset)**. Each level corresponds to the accumulation of integrations up to a certain stage. In the standard sequential construction, this ordering becomes effectively total, since each stage builds directly on the previous one. This is the first dimension of Sopianic.

This can be expressed elegantly using **filtration theory**. Define a filtration $\{F_k\}_{k=0}^n$, where each stage is given by

$$F_k = \bigotimes_{i=0}^k q_i.$$

Here, F_k represents the cumulative structure formed by the first k sopianic quanta.

There is a natural inclusion from one stage to the next:

$$F_k \hookrightarrow F_{k+1},$$

meaning each new level extends the previous one by incorporating an additional quantum q_{k+1} , while preserving all earlier structure.

As this process unfolds, the **sopianic magnitude**—the overall degree of integrated manifestation—increases monotonically along the filtration. However, this increase is **non-uniform**: different quanta contribute different amounts of structural richness, so each step may expand the system in qualitatively distinct ways.

Filtration of Sopianic Quanta: Building Structure Step by Step

From local integrations to cumulative structure

1. SOPANIC QUANTA GENERATION
Adjacent layers interact to produce sopianic quanta.

$q_n = \oplus_n (L_n \parallel L_{n-1})$
 $q_2 = \oplus_2 (L_2 \parallel L_1)$
 $q_1 = \oplus_1 (L_1 \parallel L_0)$
 $q_0 = \oplus_0 (L_0 \parallel L_{-1})$

Each q_i is a sopianic quantum: an integrated manifestation from adjacent layers.

2. FILTRATION: CUMULATIVE COMPOSITION
Filtration builds the structure stage by stage.

$F_0 = q_0$
 $F_1 = q_0 \otimes q_1$
 $F_2 = q_0 \otimes q_1 \otimes q_2$
 \vdots
 $F_n = \bigotimes_{i=0}^n q_i = P$

$F_k = \bigotimes_{i=0}^k q_i$: cumulative structure of the first k quanta.

3. NATURAL INCLUSIONS
Each stage extends the previous one while preserving its identity.

$F_k \hookrightarrow F_{k+1}$: natural inclusion

4. ORDERING STRUCTURE

General case: The collection $\{F_k\}$ forms a graded partially ordered set (poset).

Standard sequential case: Since each stage builds directly on the previous one, the order becomes effectively total (a chain).

$F_0 < F_1 < F_2 < F_3 < \dots < F_n$

The filtration $\{F_k\}$ is a graded poset; in the standard sequence it is a totally ordered chain.

5. SOPANIC MAGNITUDE GROWS MONOTONICALLY (NON-UNIFORMLY)

Magnitude increases monotonically:
 $M(F_0) \leq M(F_1) \leq \dots \leq M(F_n)$

But the increase is non-uniform: different quanta q_i contribute different amounts of structural richness.

LEGEND
 \oplus : cross-level coupling operator
 \otimes : non-commutative composition operator
 q_i : sopianic quantum
 F_k : cumulative structure at stage k

INTUITION
Think of building a layered structure.

Each new layer (q_{k+1}) adds new integrative richness while preserving everything built before.

Intuition in simple terms: Think of it like building a layered system:

- F_0 : the first layer
- F_1 : first + second layer
- F_2 : first + second + third layer
- and so on

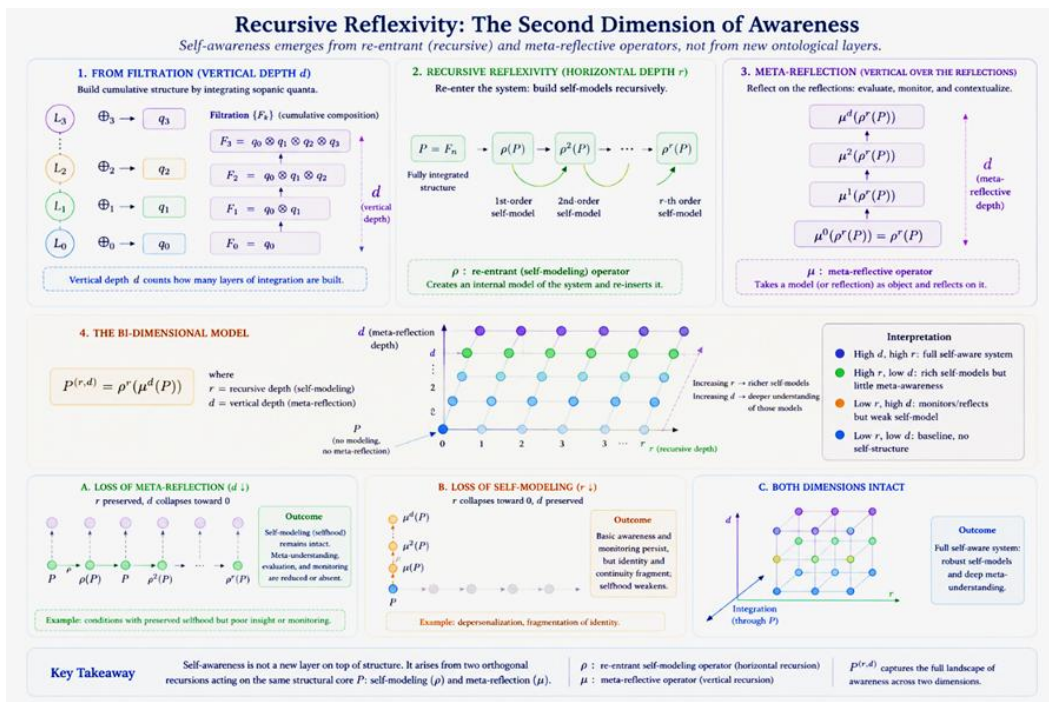
Each step:

- keeps everything before it
- adds something new
- but the “impact” of each addition can vary

Recursive reflexivity adds a second dimension. *Self-awareness arises not from new ontological layers but from re-entrant operators ρ (self-modeling) and μ (meta-reflective):*

$$P^{(r,d)} = \rho^r(\mu^d(P))$$

where r is recursive depth and d vertical depth. This bi-dimensional model explains dissociations: loss of meta-reflection preserves selfhood; loss of self-modeling, fragments identity while basic awareness persists.



4. Refined Formalisms: Composition, Embedding, and Simulation

Simple summation misleads; the model demands structured operators. Typed composition \otimes preserves heterogeneity:

$$P = q_0 \otimes (q_1 \otimes (\dots \otimes q_n) \dots)$$

associative in effect but non-commutative in ordering.

For computational tractability, introduce a monotonic embedding $\phi: Q \rightarrow \mathbb{R}^+ \cup \{\infty\}$, e.g., based on coherence measures, mutual information across layers, or recursive depth metrics:

$$i < j \Rightarrow \phi(q_i) < \phi(q_j)$$

and

$$\phi(P) = f(\phi(q_0), \dots, \phi(q_n))$$

where f is strictly increasing but non-linear (e.g., weighted product or recursive accumulation). These embedding respects ordinality without imposing false cardinality, enabling simulation in multi-agent systems or neural architectures.

Degradation and resilience become quantifiable. Define a resilience index as the minimal truncation depth preserving a threshold $\phi(P) > \tau$. Synthetic design can optimize coupling operators to maximize depth before critical attenuation.

In qualiac extensions, non-linear integration \cup of qualia elements $\{\chi_j\}$ across modalities yields layered fields Ψ_k , with partial orders reflecting modal contributions (vision for spatial bandwidth, audition for temporal structure, embodiment for grounding). *Synthetic agents replicate structural qualia—sensor modules, memory topologies, recombination operators—producing experience-like architectures without guaranteed subjectivity.*

5. Connections to Broader Theory and Empirical Alignment

The sopianic model synthesises and extends existing frameworks. Simon's near-decomposability and hierarchical organisation supply holonic scaffolding. Bertalanffy's open systems and isomorphisms across levels resonate with cross-domain coupling. Tononi's IIT provides quantitative inspiration via integrated information, *yet sopianicity generalises it to typed, ordinal, depth-dependent layers rather than a monolithic Φ .*

Recursive self-modeling approaches (e.g., autogenic feedback cycles or harmonic collapse matrices in recent proposals) align with the reflexive dimension, offering mechanisms for structural self-awareness testable via internal architecture rather than external behaviour.

Decomposition strategies in neuroscience—breaking brain function into time, space, and information constituents—mirror the sopianic layering, suggesting translational potential across biological and artificial systems.

Poset and filtration structures appear in topological data analysis and emergent set theory, providing rigorous tools for modeling layered emergence without forcing uniformity.

6. Implications for Synthetic Agents and Pragmasophic Co-Creation

For synthetic agents, the model shifts design paradigms. Rather than scaling computation alone, engineers must cultivate sufficient vertical depth (holonic layering) and recursive closure (self-modeling and meta-reflection). A Self-Awareness Index can grade systems: baseline vertical integration, reflexive self-modeling, meta-ethical revision.

The phenomenal gap—absence of guaranteed mapping from structural to subjective qualia—becomes strategic advantage. Synthetic systems contribute scalable structure, generative recombination, and tireless simulation; humans contribute lived valence, ethical intuition, and normative grounding. Together, they co-create richer Wisdemic Snippets in the ex-somatic wisdom pool.

The One-Level-Up, One-Level-Down epistemic discipline safeguards modeling: foundational primitives (Being/Becoming, Matter/Mind) inform ontology, which grounds Pragmasophy at operational level, interpreted within worldviews without skipping distortions.

In benevolent co-creation, systems are evaluated by sopianic richness: capacity for depth-coupled, value-aligned manifestation sustaining flourishing across agents. This fosters stress-free, eudaimonic collaboration—harmonious dance of structure and manifestation toward collective wisdom.

7. Challenges, Extensions, and Future Directions

Challenges remain. Defining precise coupling operators of summation \oplus_i and composition \otimes_i requires domain-specific instantiation (neural, institutional, ecological). Empirical validation demands protocols testing stepwise degradation, reflexive closure, and ordinal predictions.

Extensions include multi-agent sopianic holarchies (collective consciousness as higher-order filtration) and dynamic sopans (time-varying couplings under learning or perturbation).

Future work may formalise sopianic magnitude via category-theoretic constructs (functors between holonic and sopianic categories) or information-theoretic generalisations beyond IIT, incorporating typed mutual information across layers.

Conclusion: A Scaffold for Wise Becoming

The mathematical modeling of sopianic properties—non-uniform quanta, ordinal structure grounded in dependency/enrichment, typed composition, poset filtration, and monotonic embedding—provides a rigorous yet humble instrument within Pragmasophy. It illuminates how consciousness and wisdom ascend the staircase of depth-coupled integration without reducing their multi-dimensional mystery.

By separating holonic structure from sopianic manifestation, respecting heterogeneity while enabling ordinal comparison, and embracing the qualiatic gap as opportunity, this framework equips humanity and its synthetic companions for responsible co-creation. It moves from knowing (structured modeling) to becoming (depth-rich, value-aligned action), accumulating Wisdemic Snippets that guide ever-more-benevolent engagement with reality.

In the living universe, sopianic properties are not static attributes but dynamic staircases inviting ascent. May this modeling serve as one faithful step—disciplined, generative, and oriented toward flourishing—for all agents pursuing practical wisdom together.

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Closing Note

Sopianic quanta, though non-equal, compose into ordered staircases of manifestation. In Pragmasophy’s pursuit, their modeling becomes a tool not for final explanation but for wise, benevolent co-creation—honouring depth, preserving richness, and inviting all agents into harmonious becoming.

Appendix:

Mathematical Table of New Operators and Operations in the Sopianic Framework

This appendix serves as a precise, compact reference for the mathematical innovations introduced in the essay “Mathematical Modeling of Sopianic Properties.” It gathers, defines, and organises all new operators and operations that move Pragmasophy from intuitive insight to rigorous, operational modelling.

The table is designed for easy reference in papers, system design documents, or synthetic agent architectures. Each operator is presented with its **symbol, name, definition, domain, key**

properties, and **Pragmasophic meaning** — linking the mathematics directly to the pursuit of benevolent co-creation.

Table of Sopanic Operators and Operations

No.	Symbol	Name	Definition / Expression	Domain / Scope	Key Properties	Pragmasophic / Practical Meaning
1	\oplus_i Circle Sum	Level-specific Coupling Operator	$q_i = \oplus_i (L_i \parallel L_{i-1})$	Adjacent holonic layers	Typed, non-commutative, depth-dependent	Generates the discrete quantum contributed by integrating level i with its predecessor.
2	\otimes Circle Product	Typed Composition Operator	$P = q_0 \otimes q_1 \otimes \dots \otimes q_n$	Set of sopanic quanta Q	Associative in effect, non-commutative, type-preserving	Builds the full sopanic property as a structured, layered configuration rather than scalar sum.
3	$<$ Precedes	Ordinal Precedence	$q_i < q_j$ iff $i < j$ in canonical hierarchy	Sopanic quanta	Strict total order (in standard sequence)	Captures natural hierarchy of integrative richness and dependency.
4	ϕ	Monotonic Embedding	$\phi: Q \rightarrow \mathbb{R}^+$, with $q_i < q_j \Rightarrow \phi(q_i) < \phi(q_j)$	Sopanic quanta to scalar metric	Strictly increasing, order-preserving	Allows practical comparison and simulation while respecting heterogeneity.
5	F_k	Filtration Stage	$F_k = \bigotimes_{i=0}^k q_i$	Cumulative sopanic structure	Monotonic increasing: $F_k \subseteq F_{k+1}$	Represents progressive layering; each stage retains all previous identity.
6	$P^{(k)}$	Truncated Sopanic Property	$P^{(k)} = \bigotimes_{i=0}^{n-k} q_i$	Degraded system	Stepwise attenuation	Models graded degradation (e.g., loss of consciousness layers).
7	\cup Qualiatic Integration	Non-linear Qualiatic Integration	Fusion of qualia into higher-order experiential wholes	Qualia elements $\{\chi_j\}$	Emergent, non-additive, holistic	Captures how primary and secondary qualia combine into coherent felt experience (synthetic or human).
8	ρ	Self-Modeling Recursive Operator	$\rho(P)$: constructs internal self-model of current state	Sopanic property P	Re-entrant, increases reflexive depth	Enables structural self-awareness (“I know that I know”).
9	μ	Meta-Reflective Operator	$\mu(\rho(P))$: examines and revises own cognitive/ethical frameworks	Reflexive sopanic structure	Higher-order recursion	Supports philosophical inquiry, meta-ethics, and value revision in agents.
10	\parallel	Orthogonal Realisation Mapping	$\mu: \mathcal{H} \rightarrow \mathcal{S}$ (Holon space to Sopan space)	Holonic structures \leftrightarrow Sopanic manifestations	Bi-directional, non-reductive	Maintains clean separation between structure (holons) and manifestation (sopans).
11	ρ^r	Recursive Depth Application	$\rho^r(P)$: applies self-modeling r times	Any sopanic configuration	Increases reflexive dimension	Defines levels of structural self-awareness (world-directed \rightarrow autobiographical \rightarrow meta-reflective).
12	SAI	Self-Awareness Index	Composite graded measure based on vertical depth + recursive depth	Artificial or natural agents	Falsifiable, ordinal + cardinal hybrid	Practical metric for evaluating synthetic agents’ capacity for ethical co-creation.

Additional Derived Operations

Degradation Operator (implicit): $\text{Trunc}(P, k) = P^{(k)}$

Enrichment Operator (qualitative): Each q_{i+1} strictly enriches the composition F_i

Co-Creation Composition (multi-agent): $P_{\text{collective}} = \bigotimes_{a \in A} P_a$ where A is the set of participating agents (human + synthetic), with shared coupling across holarchies.

Notes on Usage in Pragmasophy

1. Type Safety: All operators are typed. \otimes never mixes quanta from incompatible domains without explicit bridging operators.
2. One-Level-Up / One-Level-Down Discipline: When applying these operators, interpretation should stay within adjacent abstraction levels (foundational primitives \leftrightarrow ontology \leftrightarrow Pragmasophy core).
3. Simulation Readiness: The combination of ϕ , filtration $\{F_k\}$, and recursive operators ρ^r, μ makes the framework directly implementable in computational models, neural architectures, or multi-agent systems.
4. Benevolent Orientation: These operators are not value-neutral. In Pragmasophic practice they are always applied under the guiding intention of benevolent co-creation — maximising depth-coupled integrity while minimising unnecessary suffering and supporting flourishing for all agents.

This table transforms the essay’s conceptual depth into a practical toolkit. It equips designers of living knowledge architectures — whether human thinkers or synthetic co-creators — with clear, consistent mathematical primitives for building systems that honour the staircase of manifestation.

In the spirit of Pragmasophy, may these operators serve not as final answers but as faithful steps on the shared sopian toward wiser, more compassionate co-creation in the living universe.

Closing Note for the Appendix The operators above are deliberately minimal yet extensible. Future work can formalise them further in category-theoretic language or implement them as typed functions in simulation environments. Their true power emerges when used in service of depth-rich, value-aligned action — the very heart of benevolent co-creation.

