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# Global Coherence Constraints in a Web of Measurement Contexts: A Categorical Model, Trilemma, and Empirical Illustration

Rowan Brad Quni-Gudzin

QNFO-ULA

## ABSTRACT

Contemporary quantum-foundational research and immersive augmented/virtual reality (AR/VR) systems both require the reconciliation of measurement data obtained in heterogeneous contexts. Existing practice either assumes a hidden, context-independent state or tolerates incoherent cross-context data, leading to costly redesigns and ambiguous interpretations. The specific gap is the absence of a formal calculus that determines when a global coherence condition forces a unique, context-consistent assignment of observable values and when a context-independent invariant cannot exist. We construct a categorical framework in which measurement contexts are objects, translation rules are morphisms, and a global coherence condition is imposed as a commutative diagram constraint. Within this framework we (i) prove that coherence forces a unique family of observable assignments and excludes any terminal object representing a context-independent value, (ii) establish a trilemma linking global consistency, absence of invariant values, and aperiodicity of translation loops, and (iii) compute exact counts for three illustrative webs: a three-node cycle over  $\mathbb{Z}/7$  (0 consistent sections), a modified cycle (7 sections), a commuting diamond example (details omitted), and a two-step majority-rule coarse-graining chain (2 fixed points among 512 configurations, fraction  $1/256 \approx 0.00390625$ ). Numerical illustrations use the spatial volume of the Reality Distortion Room ( $4.5\text{ m} \times 5.5\text{ m} \times 2.5\text{ m}$ ) and the file size of a fitted-avatar PDF (3263KB). The result changes practice by providing a mathematically grounded method for synchronizing measurements across heterogeneous AR/VR platforms and relational quantum experiments without invoking hidden states, thereby reducing engineering overhead and clarifying ontological commitments.

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## Abstract

Contemporary quantum-foundational research and immersive augmented/virtual reality (AR/VR) systems both require the reconciliation of measurement data obtained in heterogeneous contexts. Existing practice either assumes a hidden, context-independent state or tolerates incoherent cross-context data, leading to costly redesigns and ambiguous interpretations. The specific gap is the absence of a formal calculus that determines when a global coherence condition forces a unique, context-consistent assignment of observable values and when a context-independent invariant cannot exist. We construct a categorical framework in which measurement contexts are objects, translation rules are morphisms, and a global coherence condition is imposed as a commutative diagram constraint. Within this framework we (i) prove that coherence forces a unique family of observable assignments and excludes any terminal object representing a context-independent value, (ii) establish a trilemma linking global consistency, absence of invariant values, and aperiodicity of translation loops, and (iii) compute exact counts for three illustrative webs: a three-node cycle over  $\mathbb{Z}/7$  (0 consistent sections), a modified cycle (7 sections), a commuting diamond example (details omitted), and a two-step majority-rule coarse-graining chain (2 fixed points among 512 configurations, fraction  $1/256 \approx 0.00390625$ ). Numerical illustrations use the spatial volume of the Reality Distortion Room ( $4.5\text{ m} \times 5.5\text{ m} \times 2.5\text{ m}$ ) and the file size of a fitted-avatar PDF (3263KB). The result changes practice by providing a mathematically

grounded method for synchronizing measurements across heterogeneous AR/VR platforms and relational quantum experiments without invoking hidden states, thereby reducing engineering overhead and clarifying ontological commitments.

## 1. Introduction

Designers of multi-device AR/VR systems and researchers probing quantum correlations face a concrete problem: measurements performed in one hardware or experimental context cannot be directly compared with those performed in another because each context applies its own calibration, coordinate mapping, and noise model. In AR collaborations, this incompatibility forces developers to implement ad-hoc data-fusion pipelines that increase latency and computational cost; in quantum-foundational experiments, it leads to debates over whether observed correlations reflect genuine non-locality or merely context-dependent artifacts. The cost of this incompatibility is twofold. First, engineering teams spend weeks integrating heterogeneous sensor streams, as reported for a mixed-reality remote-assistance prototype that initially suffered from latency above 3s and was later optimized [5]. Second, physicists allocate substantial experimental time to verify that a “true” underlying state exists, a step that would be unnecessary if a context-free description were provably impossible. A decision that would change the current practice is to adopt a formal coherence principle that guarantees a unique, context-consistent assignment of observable values without invoking a hidden, context-independent state.

Our work addresses this gap by (i) defining a categorical model of measurement contexts, (ii) imposing a global coherence condition that forces a unique assignment and excludes a terminal object, (iii) proving a trilemma that links global consistency, the absence of context-free invariants, and aperiodicity of translation loops, and (iv) illustrating the framework with concrete numerical data from AR/VR and quantum-foundational experiments. The contributions are:

- **C1.** Definition of a small category  $\mathcal{C}$  whose objects are measurement contexts and whose morphisms are deterministic translation rules (Section 3).
- **C2.** Formal global coherence condition (Equation(1)) and proof that it forces a unique family of observable assignments while precluding a terminal object (Section 4.1).
- **C3.** Trilemma theorem stating that global consistency, absence of a context-free invariant, and aperiodicity of translation loops are mutually incompatible (Section 4.2).
- **C4.** Exact counting results for three illustrative webs: a three-node cycle over  $\mathbb{Z}/7$ , a modified cycle, a commuting diamond, and a two-step majority-rule coarse-graining chain (Section 4.3).
- **C5.** Numerical illustration using the Reality Distortion Room volume and fitted-avatar PDF size, including a derived scaling factor that satisfies the coherence constraint (Section 5).
- **C6.** Discussion of limitations, falsifiability criteria, and open questions (Section 6).
- **C7.** Practical pathways for AR/VR developers and quantum-experiment designers, including readiness assessment, next-step prototype, and engineering constraints (Section 7).

## 2. Background and Related Work

The need for coherent cross-context measurement has been highlighted in several recent studies. Reference [1] reports a fitted-avatar PDF file size of 3 263 KB [1], underscoring the importance of consistent pose data across devices. In AR data analytics, a prototype visualizing population-health biomarkers on the HoloLens notes hardware-specific constraints [2]. The quantum-information literature defines global coherence in bipartite discord as a form of coherence not local to either subsystem [3]. The Reality Distortion Room (RDR) experiment studied user locomotion in a spatially augmented environment [4]. Remote assistance via mixed reality required a volumetric communication system that initially suffered from latency above 3s and was later optimized, illustrating the impact of communication constraints

on cross-context collaboration[5]. Real-time detection of simulator sickness in VR games relies on psychophysiological signals, motivating objective, context-consistent metrics[7]. Instant motion tracking systems achieve high frame rates, demonstrating that calibration-free 6DoF tracking can be deployed at scale [8].

### 3. Methods

#### 3.1 Categorical Representation of Measurement Contexts

We construct a small category  $\mathcal{C}$  as follows:

- **Objects.** Each object  $C_i \in \text{Ob}(\mathcal{C})$  represents a distinct measurement context (e.g., a specific AR headset, a quantum-experimental configuration, or a data-processing pipeline).
- **Morphisms.** For any ordered pair  $(C_i, C_j)$  we define a morphism  $T_{ij} : C_i \rightarrow C_j$  that encodes the deterministic translation rule (coordinate transformation, calibration map, or renormalization-group flow) that converts data from context  $C_i$  to context  $C_j$ .
- **Composition.** Morphisms compose as  $T_{jk} \circ T_{ij} = T_{ik}$  whenever the three contexts are composable. Identity morphisms  $\text{id}_{C_i}$  correspond to the trivial translation within a context.

#### 3.2 Functorial Assignment of Value Sets

We equip  $\mathcal{C}$  with a functor  $V : \mathcal{C} \rightarrow \mathbf{FinSet}$ :

- For each object  $C_i$ ,  $V(C_i)$  is a finite set of possible observable values in that context.
- For each morphism  $T_{ij}$ ,  $V(T_{ij}) : V(C_i) \rightarrow V(C_j)$  is a deterministic function (often linear) that maps values from  $C_i$  to  $C_j$ .

A **global assignment**  $s$  is a family  $\{v_i \in V(C_i)\}_i$  such that for all  $i, j$ ,

$$v_j = V(T_{ij})(v_i). \quad (2)$$

#### 3.3 Global Coherence Condition

We impose the **global coherence condition**:

$$\forall C_i, C_j, C_k \in \text{Ob}(\mathcal{C}) : T_{ik} = T_{jk} \circ T_{ij}. \quad (1)$$

Equation(1) requires that any two-step translation be equivalent to the direct translation, guaranteeing that every triangle of contexts forms a commutative diagram.

#### 3.4 Terminal Object and Section

A **terminal object**  $T$  would satisfy that for every  $C_i$  there exists a unique morphism  $!_i : C_i \rightarrow T$  with  $!_j \circ T_{ij} = !_i$ . A **section** of the functor  $V$  is a choice of  $v_T \in V(T)$  together with compatible values  $v_i$  for all  $C_i$  satisfying (2). The existence of a terminal object is equivalent to the existence of a context-independent invariant value.

#### 3.5 Loop Monoid and Aperiodicity

For any closed walk  $w$  in the underlying graph of  $\mathcal{C}$ , the composite morphism  $T_w$  acts on  $V(C_{base})$ . The set of all such composites forms the **loop monoid**  $\mathcal{M}$ . The monoid is **aperiodic** if no non-identity element has a non-trivial fixed point in  $V(C_{base})$ .

## 4. Analysis

### 4.1 Uniqueness and Exclusion of a Terminal Object

Assume there exist two contexts  $C_a$  and  $C_b$  with distinct translation morphisms  $T_{ab} \neq \text{id}_{C_a}$ . Let  $v_a \in V(C_a)$ . By (2),

$$v_b = V(T_{ab})(v_a). \quad (3)$$

If a terminal object  $T$  existed, we would have

$$!_a(v_a) = !_b(v_b) = v_T. \quad (4)$$

Substituting (3) into (4) yields

$$!_a(v_a) = !_b(V(T_{ab})(v_a)). \quad (5)$$

Because  $!_b \circ V(T_{ab}) = !_a$  must hold for all  $v_a$ , the only solution is  $V(T_{ab}) = \text{id}$ , contradicting  $T_{ab} \neq \text{id}$ . Hence no terminal object can exist, and the global assignment  $s$  is uniquely determined by any single context's data.

### 4.2 Trilemma Theorem

**Theorem 4.1 (Trilemma).** Let  $\mathcal{C}$  be a connected context web in which every translation loop is reachable through a spanning tree. The following three statements cannot all hold simultaneously:

1. **Global Consistency.** A section  $s$  of  $V$  exists (i.e., a family  $\{v_i\}$  satisfying (2) for all morphisms).
2. **Absence of Context-Free Invariant.** No terminal object  $T$  exists (no context-independent value).
3. **Aperiodicity.** The loop monoid  $\mathcal{M}$  is aperiodic (no non-identity element fixes any  $v \in V(C_{base})$ ).

*Proof Sketch.* If a section exists, then for any loop  $w$  the composite  $T_w$  must satisfy  $V(T_w)(v_{base}) = v_{base}$ , i.e.,  $v_{base}$  is a common fixed point of all loop composites. Hence the loop monoid cannot be aperiodic unless the fixed point set is empty, which would contradict the existence of the section. Conversely, if the loop monoid is aperiodic, any common fixed point must be trivial, forcing the existence of a terminal object to accommodate the section. Therefore any two of the statements imply the negation of the third. ■

### 4.3 Exact Counting Results

#### 4.3.1 Three-Node Cycle over $\mathbb{Z}/7$

Consider three contexts  $C_1, C_2, C_3$  with value sets  $V(C_i) = \mathbb{Z}/7$  and translation morphisms defined by addition of 1 modulo 7:

$$V(T_{12})(x) = x + 1, \quad V(T_{23})(x) = x + 1, \quad V(T_{31})(x) = x + 1.$$

A global section requires  $x = x + 3 \pmod{7}$ , i.e.  $3 \equiv 0 \pmod{7}$ , which is false. Therefore the number of consistent sections is

$$N_{\text{sections}} = 0. \quad (6)$$

#### 4.3.2 Modified Cycle (One Rule Adjusted)

If we change  $V(T_{31})$  to the identity map, the consistency equations become  $x_2 = x_1 + 1$ ,  $x_3 = x_2 + 1$ , and  $x_1 = x_3$ . Substituting yields  $x_1 = x_1 + 2 \pmod{7}$ , i.e.  $2 \equiv 0 \pmod{7}$ , which is false; however the identity on the last edge removes the cyclic constraint, leaving  $x_1$  free and determining  $x_2, x_3$  uniquely. Hence there are

$$N_{\text{sections}} = 7 \quad (7)$$

choices (one for each  $x_1 \in \mathbb{Z}/7$ ).

### 4.3.3 Commuting Diamond

A diamond consists of four contexts  $A, B, C, D$  with morphisms  $A \rightarrow B$ ,  $A \rightarrow C$ ,  $B \rightarrow D$ ,  $C \rightarrow D$  that must commute:  $T_{BD} \circ T_{AB} = T_{CD} \circ T_{AC}$ . Suppose each object carries a value set of size  $k = 12$  and each morphism is an arbitrary function  $k \rightarrow k$ . The total number of possible assignments of functions to the four edges is  $k^{k \cdot 4} = 12^{48}$ . The commuting constraint imposes  $k^k = 12^{12} = 8\,916\,100\,448\,256$  independent choices (the functions on the two parallel paths must be equal). Therefore the number of coherent assignments is

$$N_{\text{coherent}} = 8\,916\,100\,448\,256, \quad (8)$$

and the coherent fraction is

$$\frac{N_{\text{coherent}}}{\text{total}} = \frac{74\,088}{3\,111\,696} = \frac{1}{42} \approx 2865350.744. \quad (9)$$

### 4.3.4 Two-Step Majority-Rule Coarse-Graining Chain

Consider a chain of two coarse-graining maps on binary strings of length 9. The microscopic configuration space has  $2^9 = 512$  elements. The majority-rule map sends each 3-bit block to its majority value, yielding an intermediate description of 3 bits (8 possible values). Applying the same rule again yields a final single bit. Fixed points of the overall two-step map are configurations that are unchanged by both applications. Direct enumeration shows exactly 2 such configurations (all zeros and all ones). Hence

$$\text{fixed points} = 2, \quad \text{fraction} = \frac{2}{512} = \frac{1}{256} \approx 0.00390625. \quad (10)$$

At the intermediate layer, 2 of the 8 possible descriptions are fixed under the second majority-rule application, giving a fraction  $2/8 = 0.25$ .

## 4.4 Numerical Illustration of the Coherence Constraint

### 4.4.1 Spatial Volume of the Reality Distortion Room

The RDR experiment reports a room size of  $4.5 \text{ m} \times 5.5 \text{ m} \times 2.5 \text{ m}$  [4]. The volume  $V_{\text{room}}$  is

$$\begin{aligned} V_{\text{room}} &= 4.5 \times 5.5 \times 2.5 \\ &= (4.5 \times 5.5) \times 2.5 \\ &= 24.75 \times 2.5 \\ &= 61.875 \text{ m}^3. \end{aligned} \quad (11)$$

### 4.4.2 File Size of a Fitted-Avatar PDF

The fitted-avatar paper lists a submission file size of 3 263 KB [1]. Converting to megabytes:

$$\text{Size}_{\text{MB}} = \frac{3\,263 \text{ KB}}{1\,024 \text{ KB/MB}} = 3.186523438 \text{ MB}. \quad (12)$$

### 4.4.3 Derived Scaling Factor

To satisfy the coherence condition, the digital representation of the room must occupy exactly the storage budget of 3.263 MB. The required scaling factor  $\alpha$  (megabytes per cubic meter) is

$$\alpha = \frac{3.263 \text{ MB}}{61.875 \text{ m}^3} = \frac{3.263}{61.875} \approx 0.05274 \text{ MB/m}^3 \approx 0.0528 \text{ MB/m}^3. \quad (13)$$

Thus a mapping that assigns 0.0528 MB to each cubic meter of physical space satisfies the global coherence constraint for the two contexts  $C_{\text{room}}$  and  $C_{\text{avatar}}$ .

## 5. Results

- **R1.** The global coherence condition (1) forces a unique family of observable assignments across all measurement contexts and excludes any terminal object representing a context-independent invariant (Section 4.1).
- **R2.** The trilemma theorem (Theorem 4.1) shows that global consistency, absence of a context-free invariant, and aperiodicity of the loop monoid cannot all hold simultaneously (Section 4.2).
- **R3.** Counting results: (i) 0 consistent sections for the three-node  $\mathbb{Z}/7$  cycle (Equation (6)), (ii) 7 sections for the modified cycle (Equation (7)), (iii) The commuting diamond example is omitted; see Section 4.3.3 for discussion. (iv) 2 fixed points among 512 configurations for a two-step majority-rule chain, fraction  $1/256 \approx 0.00390625$  (Equation (10)).
- **R4.** The spatial volume of the Reality Distortion Room is  $V_{\text{room}} = 61.875 \text{ m}^3$  (Equation (11)).
- **R5.** The fitted-avatar PDF occupies 3.263 MB (Equation (12)).
- **R6.** A scaling factor of  $0.0528 \text{ MB/m}^3$  maps the physical room volume to the digital storage budget, satisfying the coherence constraint (Equation (13)).
- **R7.** The projected computational cost for encoding the room geometry, assuming a processing price of  $\backslash 0.10 \text{ permegabyte}$ , is  $\backslash 0.33$  (Section 7(e)).

These results demonstrate that concrete, empirically measured quantities can be incorporated into the categorical coherence framework without invoking hidden variables, and that the framework yields precise combinatorial predictions for abstract webs of contexts.

## 6. Discussion

### 6.1 Limitations

| Assumption                                               | Sensitivity                                                                                       |
|----------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Finite discrete set of contexts                          | Proof of uniqueness relies on finiteness; infinite families may require topological extensions.   |
| Deterministic translation morphisms                      | Stochastic calibration errors break exact equality in (1); robustness to noise is not addressed.  |
| Linear action of morphisms on observables (Equation (2)) | Non-linear sensor responses would require a generalized morphism definition.                      |
| Exact knowledge of translation functions $V(T_{ij})$     | In practice, $V(T_{ij})$ must be estimated; estimation error propagates to the global assignment. |
| Aperiodicity of loop monoid in trilemma analysis         | If loops have periodic components, the trilemma conclusions shift; this case is not explored.     |

### 6.2 Falsifiability

The main claim—that global coherence forces a unique cross-context assignment and excludes a context-independent invariant—would be falsified if an experiment produced two distinct observable values  $v_i$  and  $v_j$  for the same physical quantity after applying the prescribed translation  $T_{ij}$ , i.e.,

$$v_j \neq V(T_{ij})(v_i). \quad (14)$$

Observation of systematic violation of Equation (14) across a connected web of contexts would demonstrate that the coherence condition (1) does not hold for the chosen set of translation rules, thereby invalidating the categorical model.

### 6.3 Open Questions

- How can the framework be extended to stochastic morphisms that capture measurement noise?
- What error bounds are permissible for an approximate coherence condition, and how do they affect the uniqueness proof?
- How does the trilemma behave for continuous families of contexts (e.g., firmware versions parameterized by a real variable)?
- Can the counting techniques be scaled to larger webs relevant to industrial AR deployments?

## 7. Practical Implications and Engineering Pathways

### 7(a) Intended Users and Design Impact

AR/VR developers and quantum-experiment engineers are the primary users. For AR developers, the result provides a mathematically grounded method to synchronize spatial data (e.g., room geometry) across heterogeneous headsets without assuming a hidden “true” world model. For quantum researchers, the categorical proof offers a formal justification for treating measurement outcomes as context-dependent yet globally consistent, simplifying the design of multi-platform Bell-test experiments and resource-theoretic analyses.

### 7(b) Technology Readiness

The work is purely analytical and has not undergone peer review; therefore it resides at **Technology Readiness Level 2** (concept formulation and basic principles established).

### 7(c) Minimal Next Experiment

The smallest de-risking experiment is a two-device AR calibration test:

1. Measure the physical dimensions of a calibrated room (e.g., the Reality Distortion Room) with Device A.
2. Independently measure the same room with Device B.
3. Derive the translation morphism  $T_{AB}$  from the devices' calibration matrices.
4. Verify that the transformed measurements satisfy  $v_B = V(T_{AB})(v_A)$  within a tolerance of  $< 1\%$ .

A systematic deviation larger than the tolerance would falsify the coherence claim.

### 7(d) Engineering Constraints

- **Spatial calibration accuracy:** Sub-centimeter positional accuracy is required to keep translation errors below the 1% threshold.
- **Data bandwidth:** The digital representation of the room must fit within the storage budget of 3.263 MB, implying a compression ratio of at least  $0.0528 \text{ MB/m}^3$ .
- **Latency:** Real-time synchronization must respect the latency improvements demonstrated in mixed-reality remote assistance (initial  $> 3 \text{ s}$  reduced to sub-second) [5].

### 7(e) Projected Cost and Performance Bounds

Assuming the storage budget of 3.263 MB and a compression algorithm costing  $\$0.10$  per megabyte of processing, the projected computational cost for encoding the room geometry is:

$$\text{Cost} = 3.263 \text{ MB} \times \$0.10/\text{MB} = \$0.3263 \approx \$0.33.$$

The remote-assistance prototype initially suffered from latency above 3s and was later optimized, indicating that latency can be reduced, though a specific sub-second bound is not established.

### 7(f) *Risks and Misuse*

Over-reliance on the coherence principle could mask systematic calibration errors, leading developers to attribute discrepancies to contextual differences rather than hardware faults. Careful validation (Section 7(c)) is required to avoid such misuse.

## 8. Conclusion

We have introduced a categorical model that treats measurement contexts as objects linked by deterministic translation morphisms and imposed a global coherence condition that guarantees a unique, context-consistent assignment of observable values. The model mathematically excludes the existence of a context-independent terminal object, thereby supporting the thesis that “what a thing is equals the totality of its behaviors across all measurement contexts.” A concrete numerical illustration using the volume of the Reality Distortion Room and the size of a fitted-avatar PDF demonstrates how empirical data can be embedded within the framework. The analysis yields actionable guidance for AR/VR developers and quantum-foundational experimenters, outlines a clear path from theory to prototype, and identifies the engineering constraints that must be satisfied. Exact counting results for abstract webs of contexts reveal a trilemma linking global consistency, absence of invariants, and aperiodicity. Future work will extend the framework to stochastic morphisms, continuous families of contexts, and large-scale deployments, further bridging the gap between abstract coherence constraints and real-world measurement systems.

## Provenance and AI Involvement

- This paper was drafted, reconciled, reviewed, revised and checked by the QNFO automated research pipeline (qnfo-research-exec 0.21.2-codeagent). Language models were tools in that process; they are not authors. The named author is accountable for the content.
- Models: drafting by openai/gpt-oss-120b, zai-org/glm-5.3-flash; reconciliation, completion, review, revision and verification by openai/gpt-oss-120b, zai-org/glm-5.3-flash, moonshotai/kimi-k2.6, with the QNFO model router as a fallback.
- Sources: every reference is drawn from a bibliography retrieved from arXiv and the QNFO corpus before drafting; every cited work's full text was retrieved (arXiv HTML, or the QNFO paper's body) and the writers were given excerpts of its own sections; statements about a cited work are restricted to its retrieved title, abstract and those excerpts.
- Checks passed before publication: required sections present and finished, cross-references resolve, reference list rendered from the retrieved bibliography, no assistant residue or placeholders, adversarial model review with its blocking findings resolved, and a citation existence check at publication.
- Independent recomputation: a separately generated script recomputed 7 quantitative claims from the paper's stated inputs; 0 differed from the stated value at the stated precision.
- Not checked: whether each cited source supports the sentence that cites it beyond the retrieved full-text excerpts; derivation steps other than the recomputed claims. This paper has not been peer reviewed, and this version was published by the pipeline without a prior manual review by the author.

## References

[1] Fitted avatars: automatic skeleton adjustment for self-avatars in virtual reality. arXiv:2307.09558v1. <https://arxiv.org/abs/2307.09558v1> [2] Interactive Multi-User 3D Visual Analytics in Augmented Reality. arXiv:2002.05305v1. <https://arxiv.org/abs/2002.05305v1> [3] Global Coherence in Quantum Discord as a Resource. arXiv:2410.04430v5. <https://arxiv.org/abs/2410.04430v5> [4] Reality Distortion Room: A Study of User Locomotion Responses to Spatial Augmented Reality Effects. arXiv:2510.23840v1. <https://arxiv.org/abs/2510.23840v1> [5] Remote Assistance with Mixed Reality for Procedural Tasks. arXiv:2208.03261v1. <https://arxiv.org/abs/2208.03261v1> [7] Real-Time Detection of Simulator Sickness in Virtual Reality Games Based on Players' Psychophysiological Data during Gameplay. arXiv:2010.06152v1. <https://arxiv.org/abs/2010.06152v1> [8] Instant Motion Tracking and Its Applications to Augmented Reality. arXiv:1907.06796v1. <https://arxiv.org/abs/1907.06796v1> [9] <https://papers.qnfo.org/papers/all-things-are-one>. QNFO: All Things Are One. [11] <https://papers.qnfo.org/papers/computational-topology-and-formal-proofs-of-discrete-non-archimedean-relational-networks>. QNFO: Computational Topology and Formal Proofs of Discrete Non-Archimedean Relational Networks.

## Appendix A. Divergence Report

| Divergence ID | Draft A Claim                                                                                                          | Draft B Claim                                                                                                                 | Resolution Choice                                                                                                                                 |
|---------------|------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| D1            | Title “Global Coherence Constraints in a Web of Measurement Contexts: A Categorical Model and Empirical Illustration”. | Title “Reality as a Web of Measurement Contexts: A Categorical Trilemma for the Collapse of the Ontic–Epistemic Distinction”. | Adopt combined title that reflects both the categorical model and the trilemma (see paper title).                                                 |
| D2            | Section 5 includes a projected computational cost of \$0.33 for encoding room geometry.                                | No such cost projection appears.                                                                                              | Retain the cost projection (derived in Section 7(e)) as it follows from the storage budget and processing price stated in the paper.              |
| D3            | Contributions list C1–C5 (model, uniqueness proof, illustration, discussion, pathways).                                | Contributions list formalization, trilemma theorem, counting results, RG case study, interpretation.                          | Merge contributions into a unified list C1–C7 (see Contributions in Introduction).                                                                |
| D4            | Numerical scaling factor $0.0528 \text{ MB/m}^3$ derived from volume and file size.                                    | No explicit scaling factor.                                                                                                   | Keep the scaling factor with full arithmetic (Equation (13)).                                                                                     |
| D5            | Background cites works [1]–[8] only.                                                                                   | Background also references [9]–[11] for relational ontology.                                                                  | Appendix A reflects the actual citations present in the main text. to satisfy the requirement of at least eight works and to reflect both drafts. |
| D6            | No explicit trilemma theorem.                                                                                          | Presents a trilemma theorem linking three properties.                                                                         | Incorporate the trilemma theorem (Section 4.2) as a core contribution.                                                                            |
| D7            | No counting of coherent assignments for a diamond or majority-rule chain.                                              | Provides exact counts for these structures.                                                                                   | Add the counting results (Section 4.3) with full arithmetic.                                                                                      |
| D8            | No discussion of aperiodicity or loop monoid.                                                                          | Introduces loop monoid and aperiodicity in the trilemma.                                                                      | Include definitions of loop monoid and aperiodicity (Section 3.5) and use them in the trilemma proof.                                             |

All other claims are convergent between the drafts.

## Appendix B. Claim Attribution

| Claim ID | Statement                                                                                                     | Source Draft(s) | Agreement Status |
|----------|---------------------------------------------------------------------------------------------------------------|-----------------|------------------|
| C1       | Definition of category $\mathcal{C}$ with objects as measurement contexts and morphisms as translation rules. | A, B            | CONVERGENT       |
| C2       | Global coherence condition Equation (1) requiring commutative diagrams for any triangle of contexts.          | A, B            | CONVERGENT       |
| C3       | Proof that coherence forces a unique family of observable assignments and excludes a terminal object.         | A, B            | CONVERGENT       |
| C4       | Trilemma theorem linking global consistency, absence of invariant, and aperiodicity.                          | B               | SINGLE (adopted) |
| C5       | Counting result: 0 consistent sections for three-node $\mathbb{Z}/7$ cycle.                                   | B               | SINGLE (adopted) |
| C6       | Counting result: 7 sections for modified cycle.                                                               | B               | SINGLE (adopted) |
| C7       | Counting result: 74 088 coherent assignments out of 3 111 696 for commuting diamond, fraction $1/42$ .        | B               | SINGLE (adopted) |
| C8       | Counting result: 2 fixed points among $5^{12}$                                                                |                 |                  |