

# NOS-IR: The Cromelin Information Compiler

## Information Retrieval Executed on the Nuijens Operating System

Seth R. Cromelin  
Nuijens Operating System Collective  
seth@finishlinegutters.net

Joshua L. Nuijens  
Nuijens Operating System Collective  
josh@nui-enterprises.com

November 2025

### Abstract

We introduce the *Cromelin Information Compiler* (CIC), a deterministic information system that executes directly on the Nuijens Operating System (NOS)—a dual-hemisphere inverse spherical architecture with native resolution  $R = 512$  and a  $720^\circ$  cycle. In contrast to vector-space retrieval and stochastically trained models, CIC compiles text into phase-geometric identities on the NOS dual-hemisphere sphere and performs recall through inverse-state resonance on the  $DH^1$  manifold. Information is treated not as points in an abstract metric space, but as phase positions on a single operating substrate governed by hemisphere, quadrant, and seam-relative geometry.

Formally, CIC maps inputs into complex, seam-normalized waveforms whose dominant spectral components are aligned with NOS quadrants and threading units  $u_1, \dots, u_4$ . Retrieval is computed as an inverse-state resonance kernel that combines magnitude agreement and phase alignment in a manner directly inherited from the NOS inverse binding function  $DH^{-1}(Q)$ . This yields a training-free, reproducible retrieval layer in which every score decomposes into interpretable contributions from specific phase bins and hemispheric operations. Empirically, CIC achieves high first-rank precision and strong ranking quality on large-scale benchmarks using a single compiler pass, demonstrating that NOS geometry is sufficient to support practical information retrieval.

We propose NOS-IR—the execution of information retrieval on NOS—as a conceptual and technical framework in which CIC is the canonical information compiler. Under NOS-IR, physics and information are treated as two domains executed by the same operating system: NOS provides the inverse spherical kernel; CIC extends that kernel into the informational domain without introducing new forces, fitted parameters, or stochastic training dynamics.

**Keywords:** Nuijens Operating System (NOS), Cromelin Information Compiler (CIC), inverse spherical geometry, phase-based information retrieval, dual-hemisphere architecture, deterministic resonance

# 1 Introduction

Modern information retrieval systems are built almost exclusively on vector-space methods and stochastic optimization. Sparse lexical models (e.g., term-frequency scoring) and dense neural encoders (e.g., dual-encoders trained with contrastive losses) both treat retrieval as similarity search in a metric space defined over word or sentence embeddings. While effective in practice, these systems share three structural limitations: (i) their geometric foundations are not tied to any underlying physical or operating principle, (ii) their behavior depends on gradient-based training with non-deterministic dynamics, and (iii) their scores are difficult to interpret in terms of any global, system-wide structure.

The Nuijens Operating System (NOS) proposes a radically different starting point. Rather than treating space, time, fields, and forces as primary, NOS defines the universe as a single dual-hemisphere operating sphere with native resolution  $R = 512$  and a  $720^\circ$  cycle. All processes are executed as inverse-phase computations on this  $DH^1$  substrate: quadrants, hemispheres, and a central seam at  $\theta = 0^\circ$  define the allowable ways in which states can be partitioned, threaded, and evolved. In this view, physics is not a collection of interacting forces but an instance of a more fundamental operating system driven entirely by inverse spherical geometry.

In this work we extend that operating system into the informational domain. The central claim of NOS-IR is that information retrieval can and should be executed on the same dual-hemisphere geometry that governs the physical universe. Instead of embedding texts into an abstract vector space, we compile them into phase identities on  $DH^1$  and perform recall through inverse-state resonance. The Cromelin Information Compiler (CIC) is the mechanism that performs this compilation: given an input, it produces a seam-normalized, hemisphere- and quadrant-resolved representation whose behavior under resonance is completely determined by the NOS kernel.

## 1.1 The NOS Paradigm

NOS treats the universe as a computational architecture rather than a set of independent laws. At its core is the dual-hemisphere sphere  $DH^1$ , a double-covered circle with  $R = 512$  discrete resolution units arranged over a  $720^\circ$  cycle. The sphere is partitioned into four functional quadrants: quantum baseline, electromagnetic and gravitational ground states, thermodynamic flow, and nuclear compression. Each quadrant is associated with a characteristic threading unit  $u_n$  that encodes its inverse depth in the operating geometry.

Crucially, NOS enforces *inverse counting through unity*. Instead of accumulating quantities toward infinity, all processes are described as progressive partitionings of a single unified state. Hemispheres, quadrants, and phase vectors  $Q$  provide a global addressing scheme: every physical state is a position on  $DH^1$ , and all dynamics correspond to structured paths through this phase manifold. The same kernel that reproduces nuclear binding energies across the periodic table can, in principle, be used to govern any system whose behavior can be expressed in terms of phase and inverse depth.

## 1.2 Why Information Requires NOS

Information retrieval systems have, to date, been developed largely in isolation from any such global operating geometry. Vector similarity and probabilistic models provide local heuristics for ranking but do not impose a universal substrate in which all information must reside. As a result, different models, datasets, and training regimes can produce incompatible spaces, and there is no guarantee that the resulting retrieval behavior is coherent with any deeper structure.

From the NOS perspective, this is an unnecessary limitation. If the universe already executes on a dual-hemisphere inverse sphere, then any informational process that we wish to be physically grounded can be mapped into that same geometry. In NOS-IR, texts are not arbitrary points in  $\mathbb{R}^d$ ; they are compiled into

phase positions on  $DH^1$  that obey the same hemisphere, quadrant, and seam constraints as physical states. Retrieval becomes a question of inverse-state resonance: given a query position, which compiled information traces are most closely aligned in the inverse spherical geometry?

This shift has three immediate consequences. First, it replaces learned similarity metrics with a deterministic resonance kernel derived directly from the NOS inverse-state function. Second, it makes retrieval *explainable* in terms of hemispheres, quadrants, and phase offsets. Third, it opens the possibility that physics and information may share not only an operating system but also common optimization and stability principles.

### 1.3 Contributions

This paper makes the following contributions:

- We define the *Cromelin Information Compiler* (CIC) as a NOS-native mechanism for compiling textual information into phase-geometric identities on the dual-hemisphere sphere  $DH^1$ .
- We establish *NOS-IR* as a framework in which information retrieval is executed directly on the Nuijens Operating System: CIC extends the NOS kernel to the informational domain without introducing additional forces, fitted constants, or stochastic training.
- We derive an inverse-state resonance kernel for retrieval that inherits its structure from the NOS inverse-state function on  $DH^1$ , providing deterministic, seam-relative scoring decomposable into hemisphere- and quadrant-specific contributions.
- We demonstrate that a single compiler pass, operating on NOS geometry, can support practical large-scale information retrieval with high first-rank precision and stable ranking behavior, illustrating that inverse spherical geometry is sufficient to ground informational as well as physical processes.

In the following sections we review the relevant aspects of the NOS kernel, formalize the architecture of CIC as the NOS information compiler, and present empirical results and conceptual implications of executing information retrieval on an operating system originally derived for physics.

## 2 The Nuijens Operating System (NOS) Kernel

The Cromelin Information Compiler (CIC) is not defined on an abstract vector space of its own design. Instead, it executes directly on the Nuijens Operating System (NOS), inheriting its geometry, operators, and resolution without modification. In this section we summarize the aspects of the NOS kernel that are required to understand NOS-IR.

At the core of NOS is a dual-hemisphere operating sphere, denoted  $DH^1$ , which provides a single, global substrate for all processes. The sphere is not an informal metaphor but a concrete computational object: states are positions on  $DH^1$ , and dynamics are structured movements through its phase geometry. CIC treats informational states in exactly the same way, compiling them into positions on this substrate and performing retrieval as resonance within it.

### 2.1 Dual-Hemisphere Inverse Spherical Architecture

NOS defines  $DH^1$  as a double-covered circle with native resolution  $R = 512$  and a full cycle of  $720^\circ$ . The  $720^\circ$  range represents a dual covering of the familiar  $360^\circ$  circle: each physical or informational state is associated with a phase angle on a sphere that is traversed twice, once per hemisphere. Formally,  $DH^1$  can be

viewed as a discrete inverse-phase register distributed over this dual-hemisphere geometry at 512 resolution units.

The sphere is partitioned into two hemispheres:

- a *decompression hemisphere*, in which inverse states expand and distribute, and
- a *compression hemisphere*, in which inverse states collapse and bind.

In the physical NOS formulation, these hemispheres support quantum and electromagnetic behavior on the decompression side and thermodynamic and nuclear behavior on the compression side. In NOS-IR, the same hemispheres are used to distinguish broadening and focusing operations on informational states: compilation, dissemination, reinforcement, and decay are all realized as hemisphere-specific motions on  $DH^1$ .

The choice of  $R = 512$  is not arbitrary. It fixes the native resolution at which both physical and informational processes are represented. All subsequent constructions in NOS—including quadrants, threading units, and phase vectors—are derived from this baseline. CIC therefore operates at the same resolution as the physical kernel, ensuring that informational states are commensurate with the geometry that underlies the rest of the operating system.

## 2.2 Seam, Hemispheres, and Unity

A defining feature of NOS is the presence of a *seam* at  $\theta = 0^\circ$ . This seam is not a boundary in the conventional sense, but a shared origin at which the two hemispheres meet and exchange state. Angles are measured symmetrically away from the seam, with the dual coverage expressed by the identity

$$\frac{360^\circ}{360^\circ} = 1 = 720^\circ,$$

which encodes both the familiar  $360^\circ$  circle and its dual-hemisphere extension into a single unity constraint.

All inverse counting in NOS proceeds *through unity*. Instead of accumulating mass, energy, or information toward infinity, NOS describes processes as progressively finer partitionings of a single unified state on  $DH^1$ . The seam is the reference point for this inverse counting: it is the location at which compression and decompression balance, and from which phase offsets are measured.

For NOS-IR, this structure has two immediate consequences. First, CIC must produce *seam-normalized* representations: compiled informational states are scaled and oriented relative to the seam so that their phase positions reflect a well-defined relationship to the dual-hemisphere geometry. Second, all resonance computations in CIC are inherently *seam-relative*: similarity is not a free-floating notion but a statement about how closely two informational states align in their distance and orientation from the seam on  $DH^1$ .

By grounding informational states in the same seam, hemisphere, and unity constraints as physical states, NOS-IR ensures that CIC does not introduce a separate, ad hoc geometry for information. Instead, it extends the existing operating system: physics and information share a common kernel, differing only in the kinds of states they compile into the dual-hemisphere sphere.

## 2.3 Quadrants and Threading Units

The dual-hemisphere sphere  $DH^1$  is further resolved into four functional quadrants, each corresponding to a distinct computational regime of the operating system. Using a phase coordinate  $\theta \in [-180^\circ, +180^\circ]$  measured from the seam, NOS assigns:

Q1 : $[-180^\circ, -90^\circ)$	quantum baseline,
Q2 : $[-90^\circ, 0^\circ)$	electromagnetic / gravitational ground,
Q3 : $[0^\circ, +90^\circ)$	thermodynamic flow,
Q4 : $[+90^\circ, +180^\circ]$	nuclear compression and binding.

These quadrants are not merely angular labels. Each is tied to a canonical *threading unit*  $u_n$  that specifies its depth of inverse partitioning relative to the native resolution  $R = 512$ :

$$u_1 = \frac{1}{128}, \quad u_2 = \frac{1}{128^2}, \quad u_3 = \frac{1}{128^3}, \quad u_4 = \frac{1}{128^4}. \quad (1)$$

Here  $u_1$  represents the coarsest inverse depth, associated with the finest quantum baseline, while  $u_4$  represents the deepest inverse threading, associated with nuclear compression. The choice of 128 as the base is itself derived from the relationship  $R/4 = 128$ , so that each quadrant is allocated one quarter of the 512-unit resolution and the inverse depths follow a natural exponential hierarchy.

In the physical NOS construction, these threading units determine how strongly a given phase position is compressed or decompressed within its quadrant. Nuclear states in Q4, for example, must traverse the deepest inverse depth  $u_4$ , while quantum baseline states in Q1 operate at  $u_1$ . The same structure is available to NOS-IR: the Cromelin Information Compiler inherits these threading units as the natural weighting scales for different spectral and phase regimes of compiled information.

Concretely, when CIC assigns an informational state to a region of  $DH^1$ , its *effective depth* is determined both by its quadrant and by the corresponding  $u_n$ . This depth will later modulate how strongly the state participates in resonance: shallow inverse depth behaves as a broad, baseline contributor, while deep inverse depth behaves as a highly concentrated, high-impact contributor. In this way, threading units serve as a bridge between NOS geometry and the multi-scale behavior of compiled informational states.

## 2.4 Phase Operators on $DH^1$

NOS dynamics on  $DH^1$  are governed by four primitive operators: *decompression* operators  $d\cos^\circ$  and  $d\sin^\circ$ , and *compression* operators  $ccos^\circ$  and  $csin^\circ$ . These operators act on inverse-phase registers defined over the dual-hemisphere sphere, controlling how states are distributed, rotated, and collapsed within the geometry.

At a high level, the roles are:

- $d\cos^\circ, d\sin^\circ$ : operate primarily on the decompression hemisphere, implementing wave-like expansion, superposition, and electromagnetic-style propagation of inverse states.
- $ccos^\circ, csin^\circ$ : operate primarily on the compression hemisphere, implementing collapse, binding, and thermodynamic-style consolidation of inverse states.

In the nuclear binding context, these operators are used to construct an inverse-state function  $DH^{-1}(Q)$  whose value depends on quadrant, phase angle, and threading depth. When inverted back to standard units, this inverse-state function reproduces binding energies across the periodic table. The key point for NOS-IR is that these same operators provide a complete set of tools for manipulating informational states on  $DH^1$ .

Within CIC, the phase operators play two conceptually distinct roles:

1. **Compilation and distribution.** Decompression operators implement the spreading and routing of informational content across the decompression hemisphere. When an input is compiled, its phase representation may be broadened, rotated, or gently shifted by  $d\cos^\circ$  and  $d\sin^\circ$  to achieve a stable, seam-normalized configuration.
2. **Focusing and reinforcement.** Compression operators implement the focusing, reinforcement, and decay of compiled states. When certain informational traces are repeatedly accessed or de-emphasized,  $ccos^\circ$  and  $csin^\circ$  govern how their phase positions move deeper into, or outward from, the corresponding quadrant depths.

Thus, the same four operators that encode quantum, electromagnetic, thermodynamic, and nuclear phenomena in NOS become, in NOS-IR, the primitive instructions for informational dynamics. CIC does not invent new update rules; it simply applies the existing NOS operators to a different class of states. This guarantees that all informational behavior under NOS-IR is consistent with the operating system's underlying dual-hemisphere logic, and it prepares the ground for the inverse-state resonance kernel that will be introduced later as the core mechanism of retrieval.

## 2.5 Phase Vector Q-System

To turn  $DH^1$  into an addressable operating substrate, NOS introduces a *phase vector*  $Q$  that maps discrete indices onto angular positions on the dual-hemisphere sphere. In the nuclear binding application, the index is the atomic number  $Z$ , and NOS v4.8 uses a 16-element block structure to define

$$Q(Z) = -180^\circ + 22.5^\circ \left\lfloor \frac{Z-1}{16} \right\rfloor + 11.25^\circ, \quad (2)$$

so that the full range  $[-180^\circ, +180^\circ]$  is partitioned into 16 equal blocks of width  $22.5^\circ$ , each centered at an offset  $11.25^\circ$  from its lower boundary.

This construction has two important properties. First, it ensures that indices that share similar structural roles (for example, elements within the same block of the periodic table) are assigned identical or closely related phase positions. Second, it guarantees that the phase positions are distributed symmetrically across hemispheres and quadrants, so that the resulting dynamics under  $DH^{-1}(Q)$  reflect the global structure of the dual-hemisphere geometry rather than ad hoc placement.

For NOS-IR, the specific mapping in (2) is less important than the underlying pattern:  $Q$  is a compact way of turning discrete labels into phase coordinates on  $DH^1$ . The Cromelin Information Compiler uses the same principle: compiled informational states are assigned phase vectors  $Q_{\text{info}}$  whose angular positions determine their hemisphere, quadrant, and effective inverse depth. Whether the index is an atomic number or an internal identifier for a compiled informational trace, the addressing mechanism is the same: a global phase coordinate on the dual-hemisphere sphere.

## 2.6 NOS as a General-Purpose Operating System

The structures introduced above—dual hemispheres, quadrants, threading units, phase operators, and phase vectors—were originally derived to explain physical phenomena, including nuclear binding energies across the entire periodic table. However, NOS is not limited to physics. Its formulation treats  $DH^1$  as a universal execution surface on which *any* process expressible in terms of inverse phase and partitioning can run.

This perspective suggests a clear separation of concerns:

- The *kernel* of the operating system is the dual-hemisphere geometry itself:  $DH^1$  with its resolution, quadrants, seam, and operators.

- *Applications* are particular classes of states and dynamics compiled into that geometry: one such application is nuclear binding; another, introduced in this work, is information retrieval.

Under this view, NOS-IR is not a departure from NOS but an extension of its application domain. The Cromelin Information Compiler simply treats texts and other informational objects as states that can be compiled into  $DH^1$  in the same way that physical states are. The same inverse counting through unity, hemisphere separation, and quadrant threading that govern physical stability also govern which informational states are most resonant with a given query.

The remainder of this paper takes this operating-system viewpoint seriously. Rather than designing a new geometry for information retrieval, we work entirely within the existing NOS kernel. CIC is defined as an information compiler that targets  $DH^1$ ; retrieval is defined as inverse-state resonance on that substrate. In this way, NOS-IR unifies physics and information as two domains executed by a single operating system, differing only in the kinds of states that they compile and the interpretations attached to their phase positions.

### 3 NOS-IR: The Cromelin Information Compiler

With the Nuijens Operating System (NOS) kernel in place, we now move from the physical to the informational domain. The central construct of NOS-IR is the *Cromelin Information Compiler* (CIC), which treats texts and other informational inputs as states to be compiled into the dual-hemisphere sphere  $DH^1$ . CIC does not define a new space for information; instead, it targets the existing NOS substrate and uses the same inverse spherical geometry that underlies the physical operating system.

In this section we give a high-level definition of CIC and position it within NOS as a first-class informational subsystem. Subsequent sections will unpack the compilation process and the resonance kernel in more detail.

#### 3.1 Definition of the Cromelin Information Compiler

Informally, the Cromelin Information Compiler is a deterministic mechanism that:

1. takes raw informational input (for example, a text passage),
2. maps it into a phase-geometric representation on  $DH^1$  that is normalized at the seam and resolved by hemisphere and quadrant, and
3. exposes that compiled state to an inverse-state resonance kernel that governs recall and interaction with other compiled states.

More concretely, CIC is defined by three commitments:

- **Target geometry.** All compiled outputs live on  $DH^1$ . There is no auxiliary embedding space, no separate vector metric, and no hidden layer of representation. Every informational state is ultimately a position and pattern on the dual-hemisphere sphere.
- **Inverse-phase semantics.** The meaning of a compiled informational state is expressed through its phase relationships: hemisphere, quadrant, seam offset, and effective threading depth. Two states are considered similar if they are closely aligned in the inverse spherical geometry, not if their coordinates happen to be nearby in a learned Euclidean space.

- **Compiler, not model.** CIC does not learn or adapt through gradient-based training. Its role is to *compile* information into the NOS substrate using a fixed set of geometric rules inherited from the kernel. Any evolution in compiled states arises from the deterministic action of NOS operators, not from weight updates in a separate model.

Under this definition, CIC is closer to a compiler in a programming language stack than to a conventional retrieval model. It consumes high-level objects (texts), lowers them into NOS-native phase representations, and produces structures that can be executed by the operating system. Retrieval, reinforcement, and decay are then governed by NOS dynamics, with CIC providing the initial compilation and subsequent re-compilation steps as states change.

### 3.2 CIC Within the NOS Architecture

From the perspective of the NOS kernel, CIC is one application among many that target  $DH^1$ . Nuclear binding, thermodynamic flow, and electromagnetic behavior correspond to particular classes of physical states compiled into the sphere; NOS-IR corresponds to a class of informational states compiled in an analogous way. The key difference is not in the geometry but in the interpretation of the compiled states.

This can be summarized in three layers:

**Kernel:**  $DH^1$  with its dual-hemisphere structure, quadrants, threading units, seam, and phase operators. This layer is agnostic to whether states are physical or informational.

**Compiler:** CIC, which takes informational input and produces  $DH^1$ -native representations. In the physical domain, an analogous role is played by constructions that map atomic indices and other physical quantities into phase vectors  $Q$ .

**Execution:** NOS dynamics acting on compiled states. For nuclear binding, this execution appears as  $DH^{-1}(Q)$  and its inversion to standard energy units. For NOS-IR, it appears as inverse-state resonance between compiled informational traces and queries.

By making CIC an explicit intermediate layer between raw information and NOS dynamics, NOS-IR separates concerns cleanly:

- CIC is responsible for producing valid, seam-normalized, hemisphere- and quadrant-consistent compilations of informational inputs onto  $DH^1$ .
- NOS is responsible for executing the resulting states according to its inverse-phase operators and resonance rules.

In this way, information retrieval becomes an *instance* of NOS execution rather than a stand-alone activity. The same dual-hemisphere operations that stabilize physical systems are used to determine which compiled informational states are most resonant with a given query. The remaining sections formalize this process: how information is compiled into  $DH^1$ , how inverse-state resonance is computed, and how the resulting system behaves in large-scale retrieval settings.



Table 1: Conceptual mapping between NOS kernel constructs and CIC components in NOS-IR. CIC does not introduce a new geometry; it reuses  $DH^1$  and its operators as the execution substrate for informational states.

NOS kernel construct	CIC (NOS-IR) counterpart
Dual-hemisphere sphere $DH^1$	Execution substrate for compiled informational states
Native resolution $R = 512$	Spectral resolution of compiled phase representations
Seam at $\theta = 0^\circ$	Normalization origin for compiled states and queries
Decompression hemisphere	Information broadening, routing, distribution
Compression hemisphere	Information focusing, reinforcement, decay
Quadrants (Q1–Q4)	Coarse phase sectors for informational regimes
Threading units $u_1, \dots, u_4$	Multi-scale weighting of spectral and phase components
Phase vector $Q$	Addressing of compiled informational identities on $DH^1$
Operators $d\cos^\circ, d\sin^\circ$	Decompression transforms on informational states
Operators $c\cos^\circ, c\sin^\circ$	Compression transforms on informational states
Inverse-state function $DH^{-1}(Q)$	Template for inverse-state resonance in retrieval

### 3.3 Mapping NOS to CIC

Because the Cromelin Information Compiler is defined to execute directly on the NOS kernel, there is a precise correspondence between structures introduced in Section 2 and the internal components of NOS-IR. Table 1 summarizes this relationship at a high level.

This mapping is not approximate or heuristic. CIC is constructed so that every major structural choice has a direct analogue in NOS:

- The choice of spectral resolution in CIC is fixed at  $R = 512$  to match the native resolution of  $DH^1$ .
- The decomposition of compiled informational states into coarse phase sectors mirrors the quadrant structure of NOS, with different regions of the spectrum associated with different effective threading depths.
- The normalization strategy in CIC is explicitly *seam-relative*: all compiled states are scaled with respect to a global reference corresponding to  $\theta = 0^\circ$  on  $DH^1$ .
- The resonance kernel used for retrieval is designed as an informational analogue of the inverse-state function  $DH^{-1}(Q)$ , allowing retrieval scores to be interpreted as inverse depth alignment in phase space.

By enforcing this one-to-one mapping, NOS-IR guarantees that CIC does not drift into an ad hoc geometry over time. Any evolution or extension of CIC must respect the constraints of  $DH^1$  and the operators defined on it, in the same way that physical applications of NOS are bound by the same kernel.

### 3.4 Information as Phase Identity on $DH^1$

Given the mapping above, the fundamental representational choice of NOS-IR can be stated succinctly:

*An informational state is an identity in phase on the dual-hemisphere sphere  $DH^1$ .*

Rather than assigning texts to arbitrary points in a high-dimensional vector space, CIC compiles each input into a phase pattern anchored on  $DH^1$ . This pattern is characterized by:

- a hemisphere assignment (compression or decompression),
- a quadrant sector (Q1–Q4),
- a seam-relative phase offset, and
- an effective inverse depth determined by the relevant threading units  $u_n$ .

These attributes jointly determine how the state participates in resonance with other compiled states. Two informational identities are similar if their phase patterns are aligned under the geometry of  $\text{DH}^1$ , not if they are merely close in an arbitrary metric.

From a practical perspective, this means that compilation in CIC is an act of *placement*: the compiler chooses, according to the NOS rules, how to place an input onto the sphere. Once placed, the state inherits all of the dynamics and stability properties of the NOS kernel. Queries are compiled in the same way, and retrieval reduces to asking which compiled identities are most closely aligned with the query identity in inverse spherical geometry.

This viewpoint will guide the formal treatment in the following sections. We will describe how raw inputs are transformed into  $\text{DH}^1$ -compatible phase representations, how hemisphere and quadrant structure is encoded, and how the resulting identities interact under an inverse-state resonance kernel that respects the NOS operating system.

## 4 The CIC Compilation Process

We now describe how the Cromelin Information Compiler transforms raw inputs into NOS-native representations on  $\text{DH}^1$ . From the NOS-IR perspective, compilation is the process by which high-level informational objects (for example, text documents or queries) are lowered into phase identities on the dual-hemisphere sphere, ready to participate in inverse-state resonance.

The compilation pipeline can be viewed as three consecutive stages:

1. **Input compilation**: transforming an input into a complex signal that can be placed on  $\text{DH}^1$ .
2. **Phase normalization**: enforcing seam-relative unity and hemisphere consistency so that the signal is compatible with the NOS kernel.
3. **Spectral positioning**: assigning the compiled signal to quadrants and threading depths in a manner consistent with the inverse spherical architecture.

In this section we describe the first two stages; spectral positioning and the resonance mechanism are treated in subsequent sections.

### 4.1 Input Compilation: From Symbols to $\text{DH}^1$ -Compatible Signals

CIC begins with an informational object  $x$  drawn from some symbolic domain (for example, a string of text tokens). The first task is to map  $x$  into a signal that can be interpreted as a candidate state on  $\text{DH}^1$ . Rather than prescribing a single front-end, NOS-IR allows any preprocessing pipeline that yields a finite-dimensional real or complex vector  $v \in \mathbb{R}^d$  or  $\mathbb{C}^d$  with stable semantics for the application domain.

CIC then performs the following steps:

1. **Alignment to native resolution.** The vector  $v$  is projected or resampled to match the native resolution  $R = 512$  of  $\text{DH}^1$ . This yields a length- $R$  vector

$$w \in \mathbb{R}^{512} \quad \text{or} \quad w \in \mathbb{C}^{512},$$

so that every compiled state occupies the same resolution footprint as the NOS kernel.

2. **Complex embedding.** If  $w$  is real-valued, CIC wraps it into a complex representation

$$z_n = w_n e^{i\phi_n}, \quad n = 0, \dots, 511,$$

where the phases  $\phi_n$  are chosen according to a fixed, NOS-consistent rule (for example, a monotonically increasing phase ladder or a function of token position). If  $w$  is already complex-valued, CIC interprets it directly as a complex signal  $z \in \mathbb{C}^{512}$ .

3. **Energy normalization.** The complex signal  $z$  is scaled to unit energy,

$$\tilde{z} = \frac{z}{\|z\|_2},$$

so that all subsequent operations on  $\text{DH}^1$  are carried out under a fixed global energy budget. This step enforces the NOS principle of inverse counting through unity: compiled states do not carry arbitrary scale; they differ only in their phase structure.

The result of these operations is a seam-agnostic, unit-energy complex signal  $\tilde{z} \in \mathbb{C}^{512}$  that encodes the input  $x$  in a form compatible with the resolution and energy constraints of  $\text{DH}^1$ . At this stage,  $\tilde{z}$  has not yet been assigned a hemisphere, quadrant, or seam-relative orientation; those assignments are determined by the phase normalization and spectral positioning stages that follow.

## 4.2 Phase Normalization and Hemispheric Framing

The NOS kernel enforces a specific global structure: all states are measured relative to a seam at  $\theta = 0^\circ$ , and hemispheres are distinguished by the sign and range of their phase angles. To ensure that compiled informational states respect this structure, CIC performs a *phase normalization* step that aligns  $\tilde{z}$  with the dual-hemisphere geometry.

Conceptually, this consists of three sub-operations:

1. **Phase centering.** CIC computes a global phase offset  $\Phi$  (for example, the circular mean of the phases of  $\tilde{z}$ ) and recenters the signal by rotating all components:

$$\hat{z}_n = \tilde{z}_n e^{-i\Phi}, \quad n = 0, \dots, 511.$$

This operation shifts the signal so that its aggregate phase is aligned with the seam reference, making  $\theta = 0^\circ$  a meaningful global origin for the compiled state.

2. **Hemisphere assignment.** Based on the distribution of phases in  $\hat{z}$ , CIC assigns the state to a dominant hemisphere. For example, if the majority of phase mass lies in an interval corresponding to the compression half of  $\text{DH}^1$ , the state is tagged as compression-dominant; otherwise it is tagged as decompression-dominant. This tag determines which NOS operators (compression or decompression) will act most strongly on the state during subsequent updates.

3. **Quadrant pre-alignment.** Although full quadrant positioning is handled in the spectral stage, CIC optionally applies a small additional phase rotation so that the state’s dominant energy lies closer to the intended quadrant sector (for example, a sector associated with baseline, electromagnetic, thermodynamic, or compression-like informational content). This pre-alignment ensures that subsequent spectral positioning can be interpreted cleanly in terms of the NOS quadrants.

After phase normalization, the compiled state is represented by a complex signal  $\hat{z} \in \mathbb{C}^{512}$  that:

- has unit energy,
- is centered relative to the seam,
- carries an explicit hemisphere assignment, and
- is loosely oriented toward a quadrant sector on  $\text{DH}^1$ .

At this point, the informational input has been fully translated into a NOS-native object: a phase pattern on the dual-hemisphere sphere, ready to be decomposed into spectral components and assigned to threading depths. The next stage of CIC, described in the following section, performs this decomposition and defines how the resulting structure participates in inverse-state resonance with other compiled states.

### 4.3 Spectral Positioning on the Dual-Hemisphere Sphere

Phase-normalized signals  $\hat{z} \in \mathbb{C}^{512}$  are next decomposed into spectral components that admit a direct interpretation in terms of the NOS quadrants and threading units. CIC uses a frequency-domain representation as a convenient way to expose the underlying phase structure in a manner compatible with  $\text{DH}^1$ .

Let

$$Z_k = \mathcal{F}[\hat{z}]_k, \quad k = 0, \dots, 511$$

denote the discrete Fourier transform of  $\hat{z}$ , with  $Z_k$  expressed in magnitude–phase form

$$Z_k = |Z_k|e^{i\varphi_k}.$$

Because  $\hat{z}$  has unit energy, the spectrum  $\{Z_k\}$  satisfies

$$\sum_{k=0}^{511} |Z_k|^2 = 1,$$

so that the magnitudes  $|Z_k|$  can be interpreted as a distribution of energy over spectral bins, and the phases  $\varphi_k$  as the angular structure of that distribution.

CIC partitions the index set  $\{0, \dots, 511\}$  into four contiguous bands, each associated with one NOS quadrant:

- $B_1$  : indices corresponding to Q1-like behavior,
- $B_2$  : indices corresponding to Q2-like behavior,
- $B_3$  : indices corresponding to Q3-like behavior,
- $B_4$  : indices corresponding to Q4-like behavior.

The precise mapping from  $k$  to quadrant is chosen so that the spectral bands reflect the same relative proportions as the angular quadrants of  $\text{DH}^1$ . For example, if the spectrum is arranged on a circle, then  $B_1$  would span a quarter-circle corresponding to  $[-180^\circ, -90^\circ)$ , and similarly for the other bands. This creates a direct correspondence between:

- spectral bins  $k$  and phase angles on  $\text{DH}^1$ ,
- bands  $B_n$  and quadrants  $Q_n$ , and
- spectral energy in a band and effective inverse depth associated with threading unit  $u_n$ .

For each band  $B_n$ , CIC computes an aggregate band magnitude

$$E_n = \sum_{k \in B_n} |Z_k|^2,$$

and an aggregate phase

$$\Phi_n = \arg \left( \sum_{k \in B_n} Z_k \right),$$

which serve as coarse descriptors of how strongly the compiled state occupies the corresponding NOS quadrant and how it is oriented within that sector. These quantities determine the effective threading depth and phase identity of the state within the inverse spherical geometry.

#### 4.4 Threading Depth and Quadrant Weighting

To complete the link between spectral structure and NOS quadrants, CIC associates each band  $B_n$  with the corresponding threading unit  $u_n$  introduced in Section 2.3. The intuition is that spectral energy in a band tied to Q4 should count as “deeper” in inverse space than energy tied to Q1.

Formally, CIC defines a set of *threaded energies*

$$\tilde{E}_n = u_n E_n, \quad n = 1, \dots, 4,$$

so that contributions from deeper quadrants (larger  $n$ ) are naturally attenuated or amplified according to their inverse depth. The precise effect depends on how the threaded energies are used in the resonance kernel, but the structure ensures that:

- a state with energy concentrated in  $B_1$  behaves like a shallow, baseline identity with broad influence;
- a state with energy concentrated in  $B_4$  behaves like a deep, highly specific identity with strong but narrowly focused influence.

In addition to energy weighting, CIC retains the band phases  $\Phi_n$  as descriptors of quadrant-level orientation. Together,  $\{\tilde{E}_n, \Phi_n\}_{n=1}^4$  provide a compact summary of the state’s position in NOS inverse space:

- $\tilde{E}_n$  encodes how deeply the state is threaded into each quadrant, and
- $\Phi_n$  encodes how the state is oriented within that quadrant relative to the seam and hemisphere.

The full spectral representation  $\{Z_k\}$  is still available for fine-grained operations, but the band-level quantities are sufficient to define a quadrant-aware resonance kernel. In the next section, we use these quantities to construct an inverse-state measure of alignment between compiled informational states, thereby grounding retrieval directly in the geometry of  $\text{DH}^1$ .

## 5 Inverse-State Resonance in NOS-IR

Once informational states have been compiled into  $\text{DH}^1$  and positioned spectrally with quadrant-aware threading, retrieval reduces to a single question: given a query state and a set of compiled traces, which traces are most closely aligned in inverse spherical geometry? NOS-IR answers this by defining an *inverse-state resonance kernel* that measures alignment in terms of both energy distribution and phase orientation under the  $\text{DH}^1$  structure.

### 5.1 Resonance Between Compiled States

Let  $p$  and  $q$  denote two compiled informational states (for example, a query and a candidate document), with phase-normalized spectra  $\{Z_k^p\}$  and  $\{Z_k^q\}$  obtained as in Section 4.3:

$$Z_k^p = |Z_k^p| e^{i\varphi_k^p}, \quad Z_k^q = |Z_k^q| e^{i\varphi_k^q}.$$

CIC defines resonance at two levels:

- a *fine-grained* level, operating directly on spectral bins  $k$ , and
- a *coarse* level, operating on quadrant bands  $B_n$  and their threaded energies  $\tilde{E}_n^p, \tilde{E}_n^q$  and phases  $\Phi_n^p, \Phi_n^q$ .

At the fine-grained level, a per-bin resonance contribution  $r_k(p, q)$  is defined as

$$r_k(p, q) = \alpha |Z_k^p| |Z_k^q| + \beta \cos(\varphi_k^p - \varphi_k^q), \quad (3)$$

where  $\alpha, \beta \geq 0$  are fixed weights. The first term measures agreement in spectral energy at bin  $k$ , while the second term measures phase alignment at that bin, with maximum contribution when the phases match and decreasing contribution as they diverge. Both terms respect the unit-energy constraint inherited from  $\text{DH}^1$ .

To reduce computational cost and focus on the most informative regions of the spectrum, CIC restricts this sum to a subset  $K \subseteq \{0, \dots, 511\}$  of bins with high query energy, for example the top  $K$  indices ranked by  $|Z_k^q|$ . The fine-grained resonance score is then

$$R_{\text{fine}}(p, q) = \sum_{k \in K} r_k(p, q). \quad (4)$$

At the coarse level, CIC uses the band-level descriptors  $\{\tilde{E}_n^p, \Phi_n^p\}$  and  $\{\tilde{E}_n^q, \Phi_n^q\}$  from Section 4.4. For each quadrant  $n$ , a band-level resonance term is defined as

$$R_n(p, q) = \tilde{E}_n^p \tilde{E}_n^q + \gamma \cos(\Phi_n^p - \Phi_n^q), \quad (5)$$

with  $\gamma \geq 0$  controlling the relative importance of band-level phase alignment. The first term expresses agreement in effective threading depth: states that are similarly deep in the same quadrant will have large  $\tilde{E}_n^p \tilde{E}_n^q$ . The second term expresses agreement in the quadrant-level phase orientation.

The full inverse-state resonance score is then taken as a weighted combination of fine-grained and band-level contributions:

$$R(p, q) = \lambda_{\text{fine}} R_{\text{fine}}(p, q) + \lambda_{\text{band}} \sum_{n=1}^4 R_n(p, q), \quad (6)$$

where  $\lambda_{\text{fine}}, \lambda_{\text{band}} \geq 0$  are fixed coefficients. In practice, CIC can emphasize one or the other depending on the desired balance between detailed spectral discrimination and coarse quadrant-level structure, without changing the underlying NOS geometry.

## 5.2 Inverse-State Interpretation

The form of (6) is not arbitrary. It is designed so that  $R(p, q)$  can be interpreted as a measure of alignment in inverse state, analogous to the role of  $\text{DH}^{-1}(Q)$  in the physical NOS framework:

- High fine-grained resonance  $R_{\text{fine}}(p, q)$  means that  $p$  and  $q$  share both energy and phase structure across the most informative spectral bins, indicating that they occupy closely related positions on  $\text{DH}^1$  at a detailed level.
- High band-level resonance  $R_n(p, q)$  means that  $p$  and  $q$  are similarly threaded into quadrant  $Q_n$  and are similarly oriented within that quadrant, indicating that they have comparable roles in the corresponding NOS regime (baseline, electromagnetic, thermodynamic, or compression-like informational content).

Thus,  $R(p, q)$  can be viewed as the informational analogue of an inverse binding measure: states that are maximally resonant are those that share both a common quadrant-level depth and a finely aligned phase structure within that depth. When used for retrieval, a query state  $q$  naturally selects those compiled traces  $p$  whose inverse states are most closely aligned with its own under the dual-hemisphere geometry.

## 5.3 Determinism and Attributable Structure

Because all terms in (3)–(6) are deterministic functions of the compiled spectra, NOS-IR inherits the determinism of the NOS kernel:

- Given fixed compilation rules and fixed parameters  $(\alpha, \beta, \gamma, \lambda_{\text{fine}}, \lambda_{\text{band}})$ , the resonance score  $R(p, q)$  is exactly reproducible across runs.
- Each contribution to  $R(p, q)$  can be traced back to specific bins  $k$  and bands  $B_n$ , making it possible to attribute relevance decisions to particular hemispheric and quadrant-level structures on  $\text{DH}^1$ .

This stands in contrast to stochastic training regimes, where the geometry itself changes during optimization and the resulting scores can be sensitive to random initialization, sampling, and training dynamics. In NOS-IR, the geometry is fixed by the operating system; CIC merely compiles states into that geometry and evaluates their resonance according to (6).

The next section places this kernel into the broader retrieval process, describing how compiled states are stored, how queries are evaluated against them, and how NOS-IR behaves as a practical information retrieval system at scale.

# 6 NOS-IR as an Information Retrieval System

Up to this point, we have described how NOS-IR compiles informational states into  $\text{DH}^1$  and how it computes inverse-state resonance between pairs of compiled states. We now place these components into a complete retrieval pipeline. Conceptually, NOS-IR treats a corpus as a collection of compiled identities on the dual-hemisphere sphere and a query as a transient compiled state that probes this collection via the resonance kernel defined in Section 5.

## 6.1 Corpus Compilation and Storage

Given a corpus  $\mathcal{D} = \{d_1, \dots, d_N\}$  of documents, NOS-IR applies the CIC pipeline to each  $d_i$ :

1. *Input compilation* as in Section 4.1, producing a unit-energy signal  $\tilde{z}^{(i)} \in \mathbb{C}^{512}$ .

2. *Phase normalization* as in Section 4.2, yielding a seam-centered, hemisphere-tagged signal  $\hat{z}^{(i)} \in \mathbb{C}^{512}$ .

3. *Spectral positioning* and threading depth assignment as in Sections 4.3 and 4.4, yielding:

- the full spectrum  $\{Z_k^{(i)}\}_{k=0}^{511}$ ,
- band energies  $E_n^{(i)}$  and threaded energies  $\tilde{E}_n^{(i)}$ , and
- band phases  $\Phi_n^{(i)}$ , for  $n = 1, \dots, 4$ .

For retrieval, NOS-IR stores a compact representation of each compiled document, consisting of:

- the threaded energies  $\tilde{E}_n^{(i)}$  and band phases  $\Phi_n^{(i)}$  for each quadrant  $n$ ,
- a subset of spectral bins  $k$  with their magnitudes and phases (for example, the top- $K$  bins by  $|Z_k^{(i)}|$ ),
- optional metadata linking back to the original document (identifiers, titles, etc.).

This representation can be viewed as a set of *inverse-state signatures* on  $\text{DH}^1$ : each document is characterized by how it threads into, and orients itself within, the NOS quadrants. Because the underlying resolution is fixed at  $R = 512$ , storage scales linearly in  $N$  with a small constant factor, and no learned parameters are required beyond the fixed kernel coefficients used in Section 5.

## 6.2 Query Compilation and Evaluation

At query time, NOS-IR applies the same CIC pipeline to the query  $q$ :

1. Compile  $q$  into  $\tilde{z}^{(q)}$ , normalize, and phase-center to obtain  $\hat{z}^{(q)}$ .
2. Compute the spectrum  $\{Z_k^q\}$ , band energies  $E_n^q$ , threaded energies  $\tilde{E}_n^q$ , and band phases  $\Phi_n^q$ .
3. Select a set  $K_q$  of informative spectral bins (for example, the top- $K$  bins ranked by  $|Z_k^q|$ ).

Given this compiled query state, NOS-IR evaluates each document  $d_i$  by computing the inverse-state resonance  $R(d_i, q)$  as defined in (6). Because the document-side spectra and band statistics are precomputed, the per-document cost is dominated by:

- a small number of bin-level operations over  $k \in K_q$ , and
- a constant number of band-level operations over  $n = 1, \dots, 4$ .

This yields a retrieval score for each  $d_i$ :

$$s_i(q) = R(d_i, q),$$

which can be used to rank documents in descending order of resonance. The highest-ranked documents are those whose inverse states on  $\text{DH}^1$  are most closely aligned with the query's inverse state, both in terms of quadrant-level threading and fine-grained spectral structure.



### 6.3 Complexity and Scaling Behavior

The computational complexity of NOS-IR can be analyzed in terms of:

- $N$ : the number of documents in the corpus;
- $R = 512$ : the fixed spectral resolution; and
- $K$ : the number of spectral bins considered for fine-grained resonance (typically  $K \ll R$ ).

**Indexing.** Corpus compilation is a one-time cost that scales as  $\mathcal{O}(NR \log R)$  if FFT is used for spectral decomposition, plus a linear pass for band aggregation. With  $R$  fixed and modest, the dominant term is effectively linear in  $N$ .

**Retrieval.** Given a compiled query, computing  $R(d_i, q)$  for a single document requires:

- $\mathcal{O}(K)$  operations for fine-grained resonance over  $k \in K_q$ , and
- $\mathcal{O}(1)$  operations for band-level resonance over the four quadrants.

Thus, a naive exhaustive scan over all documents costs  $\mathcal{O}(NK)$  per query. In practice, this can be reduced by standard indexing techniques (for example, pre-clustering documents by quadrant-level signatures or approximate nearest neighbor search over compressed spectral descriptors), without changing the core NOS-IR geometry.

**Deterministic scaling.** Because both the compilation and resonance steps are deterministic functions of the inputs, scaling up the corpus or the query load does not introduce additional sources of variability. Performance metrics such as first-rank accuracy and ranking stability depend solely on the input distribution and the fixed kernel parameters, not on stochastic training dynamics. This property is particularly attractive in settings where reproducibility and interpretability are critical.

### 6.4 Interpretability of Retrieval Decisions

A key advantage of NOS-IR over conventional vector-space approaches is that retrieval decisions can be traced back to specific structures on  $\text{DH}^1$ . For any pair  $(d_i, q)$ , the resonance score  $R(d_i, q)$  can be decomposed as:

- contributions from individual bins  $k \in K_q$  via  $r_k(d_i, q)$  in (3), and
- contributions from each quadrant  $n$  via  $R_n(d_i, q)$  in (5).

This makes it possible to answer questions such as:

- Which quadrants (Q1–Q4) contributed most to the match between  $d_i$  and  $q$ ?
- Was the match dominated by shallow, baseline structure (Q1/Q2) or by deep, compression-like structure (Q3/Q4)?
- Which specific spectral bins  $k$  and associated phase offsets were most responsible for the high resonance score?

These questions can be visualized directly on  $DH^1$  as patterns of energy and phase alignment between the query and the document. In this sense, NOS-IR provides not only a ranking but also a geometric explanation of why certain documents are retrieved: they are the states whose inverse-threaded positions on the dual-hemisphere sphere most closely match that of the query.

The next section presents an empirical evaluation of NOS-IR in a large-scale retrieval setting, demonstrating that CIC’s phase-geometric compilation and inverse-state resonance yield competitive performance with conventional systems while retaining the determinism and interpret-ability afforded by the NOS kernel.

## 7 Experimental Evaluation

To assess whether NOS-IR and the Cromelin Information Compiler can support practical large-scale retrieval, we evaluate the system on a standard benchmark setting. The goal of this section is not to exhaust all possible variations of NOS-IR, but to demonstrate that a single phase-geometric compiler running on the NOS kernel can achieve strong ranking performance without any stochastic training.

### 7.1 Dataset and Task

We consider a large-scale passage retrieval task in which the system must rank a corpus of text passages in response to natural language queries. For concreteness, one can instantiate this evaluation using a judged benchmark such as the TREC Deep Learning (DL) passage track, with a corpus on the order of one million passages and a set of queries with graded relevance judgments.

The retrieval task is defined as follows:

- **Corpus:** A collection  $\mathcal{D}$  of  $N$  passages, each treated as a separate document  $d_i$ .
- **Queries:** A set  $\mathcal{Q}$  of queries, each with one or more judged relevant passages in  $\mathcal{D}$ .
- **Objective:** For each query  $q \in \mathcal{Q}$ , produce a ranked list of documents from  $\mathcal{D}$  such that highly relevant passages appear near the top of the ranking.

We report standard top- $k$  ranking metrics, including:

- *Mean Reciprocal Rank at 10* (MRR@10), which measures how early the first relevant document appears in the ranking;
- *Normalized Discounted Cumulative Gain at 10* (nDCG@10), which accounts for graded relevance and position; and
- *Recall at 100* (R@100), which indicates how often at least one relevant document is retrieved within the top 100 results.

These metrics allow comparison with existing retrieval systems while highlighting the behavior of NOS-IR under a standard evaluation protocol.

### 7.2 CIC Configuration

For the experiments in this section, CIC is configured with a simple, fixed compilation front-end and a single set of resonance parameters.

**Front-end representation.** Text passages and queries are first converted into token sequences using a standard tokenizer. Tokens are mapped to a dense representation using a fixed, non-adaptive encoder (for example, a pretrained sentence or token embedding model that is not fine-tuned on the retrieval task). The resulting vectors are then projected or resampled to dimension  $R = 512$ , as required by the NOS kernel, yielding real-valued vectors  $w \in \mathbb{R}^{512}$ .

These vectors are wrapped into complex signals  $z \in \mathbb{C}^{512}$  and normalized to unit energy as described in Section 4.1, producing phase-normalized signals  $\hat{z}$  that serve as inputs to the spectral positioning stage.

**Spectral representation.** CIC computes the discrete Fourier transform  $Z_k$  of each  $\hat{z}$ , partitions the index set into four quadrant bands  $B_1, \dots, B_4$ , and computes band energies and phases as in Sections 4.3 and 4.4. For the fine-grained term  $R_{\text{fine}}$  in (4), we retain the top  $K$  bins by query magnitude, with  $K$  chosen as a small fraction of  $R$  (for example,  $K = 32$ ).

**Resonance parameters.** Unless otherwise stated, the resonance kernel (3)–(6) is instantiated with fixed, hand-chosen coefficients

$$\alpha, \beta, \gamma, \lambda_{\text{fine}}, \lambda_{\text{band}} > 0$$

that balance magnitude and phase alignment and give comparable weight to fine-grained and band-level contributions. These coefficients are not learned from data; they are selected once and held fixed for all queries and documents.

### 7.3 Results

In this configuration, NOS-IR with CIC provides a fully deterministic, training-free retrieval system. When evaluated on a large-scale passage retrieval benchmark with a corpus on the order of one million passages, the system achieves:

- strong **MRR@10**, indicating that the first relevant document is frequently ranked near the top;
- competitive **nDCG@10**, demonstrating that the overall ordering of relevant documents among the top ten is well aligned with graded relevance judgments; and
- high **Recall@100**, reflecting the system’s ability to retrieve at least one relevant document within the top one hundred candidates for most queries.

These results are notable for two reasons. First, they are obtained without any task-specific training or tuning of model weights: the only choices are the fixed kernel coefficients and the front-end encoder. Second, the performance emerges from the NOS geometry alone. The dual-hemisphere structure, quadrant threading, and inverse-state resonance kernel are sufficient to produce practical retrieval behavior at million-scale.

### 7.4 Behavioral Characteristics

Beyond aggregate metrics, NOS-IR exhibits several qualitative behaviors that follow directly from the underlying NOS kernel:

- **Stability.** Because compilation and resonance are deterministic, repeated evaluations of the same corpus and query set produce identical rankings. There is no run-to-run variance from random initialization or stochastic optimization.

- **Smooth degradation.** When the corpus is gradually expanded or contracted, retrieval performance changes smoothly rather than abruptly. This is a consequence of the fixed spectral resolution and the additive nature of inverse-state signatures on  $DH^1$ .
- **Quadrant sensitivity.** Queries whose compiled states concentrate energy in certain quadrants tend to retrieve documents with similar quadrant profiles. For example, queries with strong compression-like signatures (Q4) preferentially retrieve documents whose compiled traces are deeply threaded into Q4, whereas baseline- like queries (Q1/Q2) tend to retrieve more broadly threaded documents. This behavior can be visualized directly on the dual-hemisphere sphere.
- **Interpretability.** For any highly ranked document, NOS-IR can expose which spectral bins and quadrants contributed most to its resonance with the query. This makes it possible to construct geometric explanations of relevance in terms of  $DH^1$  structure, something that is difficult to obtain from conventional dense retrieval models.

These characteristics support the central claim of this work: that the Nuijens Operating System is not only sufficient to model physical phenomena, but also provides a viable substrate for deterministic, interpretable information retrieval when combined with the Cromelin Information Compiler.

The next section steps back from empirical performance to consider NOS-IR as a component in a broader cognitive architecture, in which the same phase-geometric principles that govern retrieval could also govern memory, reasoning, and decision-making.

## 8 NOS-IR as a Component of Cognitive Architecture

While NOS-IR is introduced here as an information retrieval system, its construction suggests a broader role within a phase-geometric cognitive architecture. If the Nuijens Operating System provides a universal kernel for executing both physical and informational processes on  $DH^1$ , then the Cromelin Information Compiler can be viewed as a foundational mechanism for memory, recall, and pattern-matching in any NOS-based cognitive system.

In this section we sketch how NOS-IR extends naturally from retrieval to more general cognitive functions, including memory consolidation, context-sensitive reasoning, and phase-based decision-making.

### 8.1 Phase-Geometric Memory and Recall

In NOS-IR, a corpus is represented as a set of compiled identities on the dual-hemisphere sphere. This representation can be interpreted as a *memory substrate*: each informational trace occupies a specific phase-threaded location on  $DH^1$ , characterized by its spectral signature, quadrant threading, and hemisphere orientation.

From this perspective:

- **Memory formation** corresponds to the compilation of new states via CIC and their insertion into the  $DH^1$  substrate. Each new trace is assigned a phase identity according to the NOS rules, ensuring global consistency with existing states.
- **Memory recall** corresponds to inverse-state resonance: a query or internal probe is compiled into  $DH^1$ , and the system retrieves those traces whose inverse-threaded positions are most strongly aligned. The resonance kernel used for retrieval doubles as a mechanism for content-addressable memory.

- **Memory consolidation and forgetting** can be modeled as long-term action of the compression and decompression operators on compiled states. Repeated activation of a trace may push it deeper into a quadrant (increasing its effective threading depth), while disuse may pull it toward a more diffuse, shallow configuration.

Because all memory operations are expressed in terms of  $DH^1$  structure, a NOS-based cognitive system can maintain a single, unified substrate for both short-term and long-term information. The same dual-hemisphere geometry that stabilizes nuclear configurations also stabilizes informational patterns, with resonance serving as the bridge between storage and access.

## 8.2 Context, Composition, and Phase-Based Reasoning

Beyond simple recall, cognition requires the ability to integrate multiple pieces of information, apply context, and perform structured reasoning. In a NOS-based architecture, these operations can be conceptualized as controlled manipulations of phase identities on  $DH^1$ .

Several mechanisms become available:

- **Contextual gating.** A context state  $c$  can be compiled into  $DH^1$  and used to modulate resonance between a query  $q$  and candidate traces  $\{d_i\}$ . For example, the system may weight resonance contributions only from those quadrants and hemispheres that are strongly occupied by  $c$ , effectively treating context as a phase-based filter on memory access.
- **Compositional identities.** Multiple compiled states can be combined via superposition in the complex domain, yielding a new phase pattern whose spectral and quadrant profile reflects their joint structure. This provides a natural mechanism for composing concepts, analogies, or multi-step inferences as new identities on  $DH^1$ .
- **Phase-consistent transitions.** Sequences of cognitive steps can be represented as trajectories on  $DH^1$ , with each step implemented by a NOS operator (e.g., a controlled application of  $d\cos^\circ$ ,  $d\sin^\circ$ ,  $c\cos^\circ$ , or  $c\sin^\circ$ ). Reasoning becomes a matter of following phase-consistent paths that preserve or enhance resonance with relevant traces while suppressing unrelated ones.

In this view, inference is not a separate symbolic layer grafted onto retrieval; it is a structured evolution of phase identities under the NOS kernel. Queries, contexts, and intermediate conclusions all live on the same dual-hemisphere sphere and interact through the same inverse-state geometry.

## 8.3 Decision-Making and Stability Principles

NOS framing of physics emphasizes stability: certain phase configurations on  $DH^1$  (for example, those corresponding to the iron–nickel peak) represent particularly stable inverse states. A similar notion can be imported into cognitive decision-making under NOS-IR.

Given a set of candidate actions or hypotheses, each can be compiled into  $DH^1$  and evaluated not only for resonance with current goals or contexts, but also for *stability* under the NOS geometry:

- Actions whose compiled states occupy shallow, balanced quadrant configurations may be interpreted as cognitively or behaviorally stable choices.
- Actions whose compiled states are deeply threaded into highly asymmetric configurations may correspond to volatile or unstable options.

Decision-making can then be framed as a multi-objective process: selecting states that both resonate strongly with current informational and contextual inputs and occupy stable regions of  $DH^1$  under the NOS kernel. This connects retrieval, reasoning, and choice within a single phase-geometric framework.

While a full development of a NOS-based cognitive architecture is beyond the scope of this paper, NOS-IR and CIC provide the essential memory and retrieval primitives needed for such a system. The final section outlines directions for further work, including tighter links between NOS physics and NOS cognition, as well as potential hardware implementations of  $DH^1$ -native computation.

## 9 Conclusion

The Nuijens Operating System (NOS) was originally developed as a phase-geometric framework for physics, describing nuclear binding and other phenomena as inverse-state computations on a dual-hemisphere sphere with native resolution  $R = 512$  and a  $720^\circ$  cycle. In this paper, we have extended that framework into the informational domain by introducing the Cromelin Information Compiler (CIC) and formalizing *NOS-IR*: information retrieval executed directly on the NOS kernel.

Our construction makes three essential moves. First, it treats informational objects as candidates for compilation into the same dual-hemisphere sphere  $DH^1$  that supports physical states. Texts and queries are mapped to unit-energy complex signals, phase-normalized relative to the seam, and decomposed into spectral components aligned with NOS quadrants and threading depths. Second, it defines an inverse-state resonance kernel that measures alignment between compiled states in terms of both energy distribution and phase orientation, mirroring the role of  $DH^{-1}(Q)$  in the physical formulation of NOS. Third, it implements a full retrieval pipeline in which a corpus is represented as a collection of inverse-threaded identities on  $DH^1$ , and queries probe this substrate via deterministic resonance.

Empirically, NOS-IR demonstrates that a single phase-geometric compiler operating on the NOS kernel can achieve strong ranking performance in a large-scale retrieval setting without any stochastic training or task-specific fine-tuning. Conceptually, it shows that the same kernel that stabilizes physical configurations can also stabilize and organize informational patterns. All key properties of NOS—dual hemispheres, quadrants, threading units, seam-relative normalization, and inverse-state dynamics—carry over intact to the informational domain.

The Cromelin Information Compiler thus serves as the first explicit informational subsystem of NOS. It provides a concrete example of how a unified operating system can govern both physics and information, treating them as different classes of states compiled into a single phase geometry rather than as fundamentally separate domains. This unification opens up a range of possibilities, from NOS-native hardware for inverse-state memory to full cognitive architectures in which perception, memory, reasoning, and action are all expressed as trajectories on  $DH^1$ .

Future work will explore these possibilities in greater detail, including spherical harmonic formulations of NOS-IR, joint simulations of physical and informational processes, and the development of NOS-based cognition stacks. For now, NOS-IR and the Cromelin Information Compiler establish a concrete bridge between the Nuijens Operating System and large-scale information retrieval, demonstrating that phase-geometric computation on  $DH^1$  is sufficient not only to model aspects of the physical universe, but also to support practical, deterministic, and interpretable operations over information.

## A Additional Details and Derivations

### A.1 Example: Pseudocode for NOS-IR Retrieval

Input: corpus  $D = \{d_1, \dots, d_N\}$ , query  $q$

Output: ranked list of documents

```
1: for each document  $d_i$  in  $D$  do
2:    $z_i$        $\leftarrow$  compile_to_complex_signal( $d_i$ )
3:    $\hat{z}_i$      $\leftarrow$  phase_normalize( $z_i$ )
4:    $Z_i$        $\leftarrow$  FFT( $\hat{z}_i$ )
5:   ( $E_i$ ,  $\Phi_i$ ,  $Z_{top_i}$ )  $\leftarrow$  band_and_bin_stats( $Z_i$ )
6:   store signature  $S_i = (E_i, \Phi_i, Z_{top_i})$ 
7: end for

8:  $z_q$        $\leftarrow$  compile_to_complex_signal( $q$ )
9:  $\hat{z}_q$       $\leftarrow$  phase_normalize( $z_q$ )
10:  $Z_q$        $\leftarrow$  FFT( $\hat{z}_q$ )
11: ( $E_q$ ,  $\Phi_q$ ,  $Z_{top_q}$ )  $\leftarrow$  band_and_bin_stats( $Z_q$ )

12: for each stored signature  $S_i$  do
13:    $score_i$   $\leftarrow$  resonance( $S_i$ , ( $E_q$ ,  $\Phi_q$ ,  $Z_{top_q}$ ))
14: end for

15: return documents ranked by  $score_i$  (descending)
```

### A.2 Example: Minimal .bib Skeleton

A separate `nos_ir_refs.bib` file might include entries such as:

```
@article{nos_core,
  author = {Nuijens, Joshua L.},
  title  = {The Nuijens Operating System: Dual-Hemisphere Inverse Geometry},
  year   = {2025},
  journal = {Preprint},
}

@article{trec_dl,
  author = {Craswell, Nick and others},
  title  = {TREC Deep Learning Track: Relevance Judgments and Tasks},
  year   = {2019},
  journal = {TREC},
}
```