

ITEM #173 — IRStarmap: A General IR Layer for Structural Intelligence (DBM Runtime Contract)

Conversion Title: DBM StarmapIR/IRStarmap 扩展

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Abstract

This item formalizes **IRStarmap** as a general-purpose Intermediate Representation (IR) layer for the Digital Brain Model (DBM).

By decoupling **structural expression (IR)** from **computational strategies (Runtime / Providers)**, IRStarmap significantly lowers the adoption barrier of Structural Intelligence, enabling domain engineers to contribute without deep knowledge of DBM internals while preserving full computational power on the framework side.

1. Motivation: From Algorithm-Centric DBM to IR-Centric DBM

The original **IStarmap** interface has proven to be a highly effective abstraction, unifying:

- Phase-1 retrieval (Euclidean Differential Trees),
- Phase-2 re-ranking (Metric Differential Trees),
- Sub-structure matching (CCC and interpretability).

However, binding **data representation** and **algorithmic implementation** within the same interface introduces long-term limitations:

- IR becomes unstable across algorithm evolution,

- Application engineers must understand DBM internals,
- Cross-domain adoption remains costly.

To address this, DBM introduces **IRStarmap** as a **stable, algorithm-agnostic IR layer**, elevating DBM from a research framework to a scalable engineering platform.

2. Core Principle: IR Is Data, Not Behavior

IRStarmap must never directly implement DBM algorithms.

Instead:

- **IRStarmap** is a *pure structural carrier*,
- **IStarmap** is a *runtime computational contract*,
- Algorithms reside in **Runtime / Provider modules**.

This separation ensures:

- Long-term stability and DOI-grade reproducibility of IR,
 - Independent evolution of algorithms,
 - Clear division of labor between application and framework teams.
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3. IRStarmap Structure (Application-Facing Contract)

IRStarmap encapsulates a **lossless tiered structural expression**, building directly on ITEM #166 (Lossless Membership Ladder):

- `tieredLadder4IR`
A structured, ordered, lossless ladder representing hierarchical membership and semantics.
- Optional Phase-1 features
Optimized for recall, not semantic completeness.
- Provenance and versioning fields
Supporting auditability, evolution, and long-term reuse.

Application engineers are only required to **compile their domain problems into this IR format**.

4. Runtime Architecture (DBM-Facing Contract)

DBM consumes IRStarmap through a **runtime adaptation layer**:

- **IRStarmap** → adapted into → **IStarmap runtime view**
- Runtime binds IR with:
 - Phase-1 feature providers,
 - Distance providers (e.g., LadderDistance),
 - Sub-structure matching providers (CCC),
 - Normalization and canonicalization providers.

This architecture allows multiple algorithms to coexist and evolve without altering IR definitions.

5. Provider Model: Controlled Evolution of Intelligence

All algorithmic variability is isolated into **Providers**, including:

- Phase-1 feature extraction,
- Phase-2 distance computation,
- Sub-structure matching and explanation,
- Structural normalization and evidence tracing.

Providers are replaceable, composable, and domain-specific, forming the evolutionary surface of DBM without destabilizing its core.

6. Engineering Conclusion (Normative Decision)

This item establishes the following **non-reversible design rule** for DBM:

IRStarmap MUST NOT extend or implement IStarmap.

IR is a stable structural asset; algorithms belong exclusively to runtime and provider layers.

This decision:

- Enables large-scale adoption of Structural Intelligence,
 - Protects DBM's long-term architectural integrity,
 - Transforms DBM into an IR-centric, ecosystem-ready platform.
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7. Position in DBM-COT

- ITEM #166 defines *how structure is expressed losslessly*.
- **ITEM #173 defines how that structure becomes a universal, industrial-grade IR contract.**

Together, they form the foundation for DBM's next phase: **structural intelligence at scale**.

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摘要

本条目正式提出 **IRStarmap**，作为数字脑模型（DBM）的**通用中间表示层（IR Layer）**。

通过将**结构表达与算法计算**彻底解耦，IRStarmap 显著降低了结构智能的工程门槛，使应用工程师仅需输出 IR，而 DBM 框架侧专注于索引、搜索、度量与解释。

1. 动机：从“算法中心”走向“IR 中心”的 DBM

原始的 **IStarmap** 接口成功统一了：

- Phase-1 粗检索（欧氏差分树），
- Phase-2 精重排（度量差分树），
- 子结构匹配与解释（CCC）。

但若将**数据结构与算法实现**绑定在同一类型体系中，会带来长期隐患：

- IR 难以稳定版本化，
- 应用侧必须理解 DBM 内核，

- 生态扩展成本过高。

因此，DBM 正式引入 **IRStarmap**，作为算法无关、长期稳定的结构 IR 层。

2. 核心原则：IR 是结构资产，不是算法载体

IRStarmap 不应、也绝不能直接实现 DBM 算法。

清晰的职责划分是：

- **IRStarmap**：纯结构表达（数据）
- **IStarmap**：运行时计算视图（行为）
- **Runtime / Providers**：算法实现与演化载体

这一原则确保：

- IR 可长期冻结、可 DOI 化、可复用，
 - 算法可独立演进、替换、并存，
 - 应用侧与框架侧职责彻底解耦。
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3. IRStarmap 结构（面向应用工程）

IRStarmap 以 **ITEM #166** 的无损隶属梯次表达为核心，包括：

- `tieredLadder4IR`
有序、分层、无损的结构梯次表达；
- 可选 Phase-1 特征
用于召回优化，而非语义完整性；
- 版本与溯源信息
支持演化、审计与长期复现。

应用工程师的唯一任务：

将业务问题完整、无损地编译为该 IR 结构。

4. 运行时架构（面向 DBM 框架）

DBM 通过运行时适配层消费 IR：

- **IRStarmap** → 适配 → **IStarmap** 运行时视图
- 运行时绑定：
 - Phase-1 特征生成器，
 - Phase-2 距离计算器（如 LadderDistance），
 - 子结构匹配与解释模块（CCC），
 - 归一化与规约模块。

算法如何变化，不影响 IR 定义。

5. Provider 模式：结构智能的演化接口

所有算法差异统一封装为 **Provider**：

- 检索特征 Provider，
- 距离 Provider，
- 子结构与解释 Provider，
- 规约与证据链 Provider。

它们是 DBM 的“演化器官”，而非结构本体。

6. 工程定型结论（不可逆设计决策）

本条目正式确立 DBM 的强约束设计规则：

IRStarmap 不得继承或实现 IStarmap。

IR 是稳定结构资产，算法只存在于运行时与 Provider 层。

这一决策：

- 从根本上降低结构智能应用门槛；
 - 保护 DBM 的长期体系一致性；
 - 使 DBM 成为 IR 驱动、可生态化的结构智能平台。
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7. 在 DBM-COT 中的位置

- ITEM #166 解决“如何无损表达结构”；
- ITEM #173 解决“如何让这种表达成为通用工业 IR 契约”。

二者共同构成 DBM 走向规模化落地的核心基础。
