

ITEM #223 - Observer-Centric Trajectory Time-Series IR Schema

Conversation：飞行器与动物轨迹分析

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ME：

很棒。谢谢啦。请生成 ITEM #223：Observer-Centric Trajectory Time-Series IR Schema。

AI：

下面我将正式生成并固化 DBM-COT ITEM #223，作为 #222 的直接技术承接项。

该 ITEM 的定位是：IR 规格级（Schema / Contract / Design Spec），为后续算法、代码骨架、JUnit MVP 提供“不可歧义的技术锚点”。

全文继续严格使用“我们”视角。

DBM-COT ITEM #223 (EN)

Title

Observer-Centric Trajectory Time-Series IR Schema

Positioning

This item specifies the formal Intermediate Representation (IR) schema for observer-centric motion trajectories within the DBM Time-Series framework. It defines the structural layers,

invariants, and extensibility rules required for flight and animal motion trajectories to enter the DBM 10-Step Structural Intelligence pipeline.

This schema is intentionally minimal, observer-relative, and structure-first.

1. Design Objectives

The Observer-Centric Trajectory Time-Series IR must satisfy the following core objectives:

1. **Observer-Centric Consistency**
All representations are defined relative to the observer's coordinate frame. No global reconstruction is assumed or required.
2. **Structural Stability**
Small sensing noise or sampling variation must not cause structural collapse or category drift.
3. **Metric Comparability**
IR instances must support meaningful distance computation for clustering, matching, and ranking.
4. **Mutation Compatibility**
The IR must admit systematic structural mutation to generate pattern families (Step-5).
5. **10-Step Pipeline Alignment**
The IR must directly support DBM's existing Time-Series steps without semantic impedance mismatch.

2. Input Assumptions

We assume a sensing pipeline (camera, radar, lidar, or fusion) capable of producing a time-indexed sequence:

$$T = \{ t_0, t_1, \dots, t_n \}$$

At each time t_i , the observer can estimate relative motion attributes with bounded uncertainty.

No assumption is made about uniform sampling, full visibility, or continuous tracking.

3. IR Layered Schema Overview

The IR is defined as a **multi-layer, loss-aware structural encoding**:

```
Trajectory IR
├─ L0: Differential Signal Layer
├─ L1: Local Motion Geometry Layer
└─ L2: Structural Event Layer
```

└─ L3: Pattern Family Signature Layer

Each layer is independently evolvable but structurally composable.

4. L0 – Differential Signal Layer (Primitive IR)

Purpose:

Capture minimal, noise-tolerant temporal change.

Schema (per time step):

- $\Delta r(t_i)$: radial distance delta
- $\Delta \theta(t_i), \Delta \phi(t_i)$: angular deltas (or 2D projection equivalents)
- $\text{sgn}(\Delta r), \text{sgn}(|\Delta \theta|)$: directionality symbols
- Δt : time delta (explicit)

Notes:

- Absolute coordinates are intentionally excluded.
- L0 is not used directly for prediction, only as a foundation.

5. L1 – Local Motion Geometry Layer

Purpose:

Abstract local geometric tendencies from raw differentials.

Derived Attributes (windowed or pointwise):

- Tangential vs radial motion ratio
- Turning tendency (curvature sign / magnitude class)
- Speed regime (slow / cruising / burst)
- Acceleration polarity (stable / accelerating / braking)

Design Principle:

All features must be derivable from L0 without external knowledge.

6. L2 – Structural Event Layer

Purpose:

Convert continuous motion into discrete, interpretable structural events.

Event Types (non-exhaustive):

- Approach
- Retreat
- Orbit / Loop
- Zigzag
- Hover / Stall
- Sudden maneuver
- Direction reversal

Event Properties:

- duration
- dominance (primary / secondary)
- confidence (derived from signal coherence)

Events form an **ordered sequence**, not a bag.

7. L3 – Pattern Family Signature Layer

Purpose:

Enable indexing, matching, and mutation at the structure level.

Signature Components:

- Event sequence skeleton (types only)
- Event duration ratios
- Dominant geometry profile
- Optional periodicity markers

Key Constraint:

Two trajectories with similar L3 signatures must be close in metric distance, even if their raw signals differ.

8. Structural Invariants

The following invariants must hold across the IR:

1. **Observer Frame Invariance**
No L2/L3 structure may depend on global coordinates.
2. **Monotonic Time Ordering**
All structures preserve causal order.
3. **Noise Monotonicity**
Added noise may reduce confidence but must not invent new structure.
4. **Mutation Closure**
IR mutation must not violate schema validity.

9. IR Mutation Rules (Step-5 Compatibility)

Permitted mutation dimensions include:

- Event boundary jitter
- Duration scaling
- Event insertion/deletion (with penalty)
- Geometry intensity smoothing

Mutation produces **structurally nearby IRs**, not arbitrary variants.

10. Distance Compatibility

Each layer contributes to distance computation:

- L0/L1: fine-grained cost
- L2: event alignment cost
- L3: signature mismatch penalty

Distance is **explainable and decomposable**, not opaque.

11. Relationship to DBM Runtime

This IR schema is designed to be directly consumed by:

- Structural Indexers
- Metric Searchers
- Pattern Family Generators
- Prediction-by-Continuation Engines

No runtime component is allowed to assume information not present in the IR.

12. Scope and Non-Goals

Explicitly out of scope:

- Full 3D world reconstruction
- Agent intention inference
- Physics-based simulation

These may exist downstream but are not prerequisites.

13. Summary

This item defines the minimal yet complete IR contract required for observer-centric motion trajectories to participate in DBM Structural Intelligence. It preserves DBM's core philosophy: structure over reconstruction, evolution over fitting, and observer-centric realism over god-view abstraction.

DBM-COT ITEM #223 (中文)

标题

以观察者为中心的运动轨迹 Time-Series IR 规格 (Schema)

定位

本 ITEM 定义 DBM 时间序列体系中，面向飞行器与动物运动轨迹的 Observer-Centric Trajectory Time-Series IR 的正式规格。该规格用于约束 IR 的层次结构、不变量与可扩展规则，使运动轨迹能够无歧义地进入 DBM 十步结构智能流水线。

这是一个**结构规格级**而非**算法实现级**文档。

一、设计目标

该 IR 必须满足以下核心目标：

1. **观察者中心一致性**

所有表示均相对于观察者坐标系定义，不依赖全局坐标。

2. **结构稳定性**

感知噪声或采样抖动不应导致结构类别坍塌。

3. **度量可比较性**

IR 实例之间必须支持有意义的距离计算。

4. 结构变异兼容性

IR 必须支持系统性的结构变异 (Step-5) 。

5. 十步法对齐

不引入与既有 DBM Time-Series 流程的语义冲突。

二、输入假设

我们假设感知系统可产生时间序列：

$$T = \{ t_0, t_1, \dots, t_n \}$$

在每个 t_i ，可估计相对距离、角度及其变化量，允许不均匀采样、遮挡与不完整观测。

三、IR 分层总览

IR 定义为多层结构编码：

Trajectory IR

- └ L0：差分信号层
- └ L1：局部运动几何层
- └ L2：结构事件层
- └ L3：模式族签名层

各层独立演化，但结构上严格组合。

四、L0：差分信号层

目的：

捕获最小、抗噪的时间变化信息。

字段：

- $\Delta r(t_i)$ ：径向变化

- $\Delta\theta(t_i)$ 、 $\Delta\varphi(t_i)$ ：角度变化
- 方向符号（接近 / 远离 / 转向）
- Δt ：时间差

说明：

- 明确排除绝对坐标。
- 仅作为底层支撑，不直接用于预测。

五、L1：局部运动几何层

目的：

从差分中抽象局部几何趋势。

典型属性：

- 径向 / 切向运动比例
- 转向趋势（曲率符号）
- 速度区间（慢 / 巡航 / 爆发）
- 加速度极性

六、L2：结构事件层

目的：

将连续运动转化为离散、可解释的结构事件。

事件示例：

- 接近
- 远离
- 盘旋

- 之字形
- 悬停
- 突发机动
- 方向反转

事件形成有序序列。

七、L3：模式族签名层

目的：

支持索引、匹配与结构变异。

签名组成：

- 事件类型骨架
- 事件持续时间比例
- 主导几何轮廓
- 可选周期性标记

约束：结构相近 → 距离必须相近。

八、结构不变量

1. 不依赖全局坐标
 2. 保持时间因果顺序
 3. 噪声只降低置信度，不生成新结构
 4. 变异后 IR 仍合法
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九、IR 变异规则 (Step-5)

允许的变异包括：

- 事件边界微调
- 持续时间缩放
- 受罚插入 / 删除事件
- 几何强度平滑

十、距离计算对齐

- L0/L1：细粒度代价
- L2：事件对齐代价
- L3：结构签名惩罚

距离可解释、可分解。

十一、与 DBM Runtime 的关系

该 IR 直接供以下模块消费：

- 结构索引器
- 度量搜索器
- 模式族生成器
- 结构延展预测器

任何运行时不得假设 IR 之外的信息。

十二、非目标说明

本 ITEM 不包含：

- 世界模型重建
- 意图推断
- 物理仿真

十三、小结

本 ITEM 定义了观察者中心运动轨迹进入 DBM 结构智能体系所需的最小且完备的 IR 合约，是后续算法、代码与实验的技术地基。

如果你认可，#222（立题） + #223（IR 规格）已经形成一个完整、严谨、可对外发布的 **DBM 分支入口**。

下一步我们可以非常自然地进入：

- **ITEM #222：Observer-Centric Trajectory Known Pattern Families**
- 或 **Java 8：TrajectoryIR / EventExtractor / SimpleMetricSearcher MVP**

我们继续推进。