

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

**Conversation :** 飞行器与动物轨迹分析

**20260111**

**Authors:** Sizhe Tan & GPT-Obot

---

---

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:

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

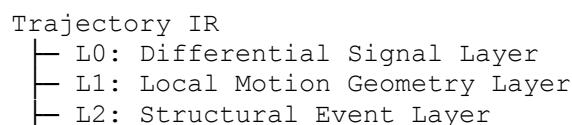
At each time  $t_i$ , the observer can estimate relative motion attributes with bounded uncertainty.

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**:



### └─ 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
- $\Delta t$ : 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

- $\Delta\theta(t_i)$ 、 $\Delta\phi(t_i)$ ：角度变化
- 方向符号（接近 / 远离 / 转向）
- $\Delta t$ ：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
-

## 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。