ITEM #228 - Motion Time-Series IR in Interaction and Physical Fields: Relational and Background Structures

Conversation：运动轨迹 Time-Series IR

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DBM-COT ITEM #228 (EN)

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Abstract

This item extends the minimal Motion Time-Series IR framework by addressing two fundamental real-world factors: adversarial interaction and asymmetric physical fields. Using aerial dogfights and gravity-affected flight as motivating examples, we argue that opponent influence and gravity must not be embedded into raw motion IR primitives. Instead, they should be modeled as parallel relational IR layers and background field interpretations, preserving the stability, comparability, and structural integrity of the minimal motion IR.

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1. Problem Statement

In real motion systems, especially in aerial combat and biological locomotion:

1. A moving agent's trajectory is strongly influenced by **other agents** (opponents, predators, collaborators).
2. Motion occurs under **asymmetric physical fields**, such as gravity, which bias movement cost and feasibility.

A naïve approach would attempt to encode these effects directly into motion deltas. This item demonstrates why such an approach is structurally incorrect, and proposes a layered alternative aligned with DBM Structural Intelligence principles.

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2. Adversarial Interaction: Why Opponents Must Not Pollute Self Motion IR

2.1 The Temptation and Its Failure

Given a self motion IR defined as:

```
Self-IR[k] = (Δpos_self[k], Δdir_self[k])
```

it may appear convenient to directly incorporate opponent effects into these deltas.

However, doing so causes:

- Loss of **self-behavior invariance**
- Incomparability across different opponents
- Contamination of pattern libraries and metric spaces

This violates the DBM requirement that IR primitives remain **structurally stable and reusable**.

2.2 Correct Modeling: Relational Motion IR

Opponent influence must be modeled as a **parallel relational structure**, not as noise.

We introduce a **Relational IR layer**, for each time step *k*:

```
Relative-IR[k] = (
    Δrange[k],      // change in distance to opponent
    Δbearing[k],    // change in relative bearing
    Δaspect[k]      // change in attack/defense geometry
)
```

These variables describe **interaction geometry**, not self motion.

2.3 Layered IR Architecture for Dogfight Scenarios

A structurally sound representation consists of three decoupled layers:

```
Layer A: Self Motion IR
    (Δpos, Δdir)

Layer B: Relational Interaction IR
    (Δrange, Δbearing, Δaspect)

Layer C (optional): Opponent Motion IR
    (Δpos_op, Δdir_op)
```

Each layer is independently searchable and comparable, while higher-level reasoning may combine them.

2.4 Explanation Chains in Interaction Contexts

When distance metrics produce explanation evidence (top-k contributing indices), the layered IR allows interpretation such as:

- Self-IR: abrupt turns and acceleration
- Relational-IR: rapid distance collapse and bearing inversion

This yields **structural evidence of forced maneuvering**, rather than opaque numerical deviation.

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3. Gravity and Physical Asymmetry: Background Fields, Not Actions

3.1 The Nature of the Gravity Problem

Gravity introduces:

- Direction-dependent motion cost
- Vertical asymmetry (up vs. down)
- Long-term bias rather than discrete action

Embedding gravity directly into motion IR deltas incorrectly conflates **environmental constraints** with **agent behavior**.

3.2 Reference-Frame Alignment as the First-Order Solution

Before computing directional deltas, motion vectors should be expressed in a gravity-aligned local frame:

```
Local Frame:
    Z-axis: opposite gravity
    X-Y: horizontal plane
```

Directional change may then be decomposed into:

```
Δdir = (Δyaw, Δpitch)
```

This preserves motion structure while making asymmetry explicit.

3.3 Derived Costs as Interpretation-Layer Signals

Gravity effects are better captured as **derived, non-IR signals**, such as:

- Climb cost proxies
- Energy expenditure estimates
- Vertical maneuver penalties

These belong to interpretation, evaluation, or tactical layers — not to raw IR.

3.4 Core Principle

Gravity is a field, not an action.

Just as market conditions are not individual trades, physical fields are not motion primitives.

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4. Unified Structural View

Combining interaction and physical field considerations yields a clean hierarchy:

```
Minimal Motion IR
    ↓
Relational Interaction IR
    ↓
Background Field Interpretation
    ↓
Pattern Matching, Metrics, Evidence
```

Each layer remains structurally pure, independently evolvable, and analytically meaningful.

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5. Key Takeaway

In structural intelligence, opponent influence and gravity must be modeled as relational and background fields, respectively. They participate in inference through parallel IR layers and interpretation mechanisms, rather than contaminating minimal motion differential primitives.

This principle enables robust modeling of complex motion systems, from aerial combat to biological behavior, within the DBM Time-Series IR framework.

DBM-COT ITEM #228（中文）

交互与物理场中的运动 Time-Series IR：关系结构与背景结构

摘要

本文在最小运动 Time-Series IR 框架之上，系统讨论了两个现实中不可回避的因素：对抗性交互与物理场不对称性。以空战格斗与重力影响下的飞行为例，本文指出，对手扰动与重力效应不应被直接编码进运动 IR 原语，而应分别建模为**关系型 IR 层**与**背景物理场解释层**，以保持运动 IR 的结构稳定性与可复用性。

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1. 问题背景

在真实运动系统中：

1. 个体轨迹往往强烈依赖于**其他运动体**（对手、捕食者、协作者）。

2. 运动发生在具有方向不对称性的**物理场**中（如重力）。

若简单将这些因素混入运动差分，将破坏 IR 的结构纯度与可比较性。

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2. 对抗交互：为何不能污染自体运动 IR

2.1 直觉式做法的问题

自体运动 IR 定义为：

```
Self-IR[k] = (Δpos_self[k], Δdir_self[k])
```

若将对手影响直接并入其中，会导致：

- 自体行为结构失稳
- 不同对手下 IR 不可比
- 模式库与距离空间被系统性污染

2.2 正确方法：关系型运动 IR

对手影响应被视为**关系结构**，而非噪声。

定义关系型 IR：

```
Relative-IR[k] = (
    Δrange[k],     // 相对距离变化
    Δbearing[k],   // 相对方位变化
    Δaspect[k]     // 攻防几何关系变化
)
```

这些量描述的是**互动几何**，而非自体动作。

2.3 分层 IR 结构（DBM 风味）

完整结构应为：

```
层 A：自体运动 IR
    (Δpos, Δdir)

层 B：关系交互 IR
    (Δrange, Δbearing, Δaspect)

层 C（可选）：对手运动 IR
    (Δpos_op, Δdir_op)
```

各层解耦，联合推断。

2.4 解释链中的价值

当距离度量给出 top-k 贡献片段时，可以清晰解释：

- 自体：急转、加速
- 关系：距离骤降、方位反转

这构成"被迫机动"的结构证据。

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3. 重力与方向不对称：背景场而非动作

3.1 重力问题的本质

重力带来：

- 上下运动代价不对称
- 长期、稳定的偏置
- 非离散动作特性

将其直接并入运动 IR，会混淆“环境”与“行为”。

3.2 参考系对齐：第一层解决方案

在计算方向变化前，将方向向量映射到重力对齐的局部坐标系：

```
局部坐标系：
    Z 轴：反重力方向
    X-Y 平面：水平
```

方向变化可分解为：

```
Δdir = (Δyaw, Δpitch)
```

结构保持，非对称性显式化。

3.3 派生代价作为解释层信号

重力影响应体现在：

- 爬升代价
- 能量代理
- 垂直机动惩罚

这些属于解释层或战术层，而非原始 IR。

3.4 核心原则

重力是场，不是动作。

正如宏观经济环境不是单笔交易，物理场不是运动原语。

4. 统一的结构视角

综合交互与物理场，形成清晰层级：

```
最小运动 IR
      ↓
关系交互 IR
      ↓
背景物理场解释
      ↓
模式匹配 / 距离 / 证据链
```

各层职责清晰，可独立演化。

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5. 核心结论

在结构智能中，对手与重力不应被视为轨迹噪声，而应分别建模为“关系结构场”与“背景物理场”，通过并行 IR 层与解释层参与推断，而不污染最小运动差分原语。
