ITEM #224 - Observer-Centric Trajectory Known Pattern Families

Conversation：飞行器与动物轨迹分析

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DBM-COT ITEM #224 (EN)

Title

Observer-Centric Trajectory Known Pattern Families

Positioning

This item defines the Known Pattern Families (KPF) for observer-centric motion trajectories within the DBM Time-Series Structural Intelligence framework. Pattern families serve as the structural bridge between raw trajectory IRs and downstream tasks such as prediction, classification, risk assessment, and explanation.

Unlike statistical clusters, Known Pattern Families are **explicit structural abstractions**, designed to be stable under noise, mutation-aware, and reusable across domains (flight, animal motion, robotics).

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1. Role of Known Pattern Families in DBM

Within DBM, Known Pattern Families play a central role:

- They **anchor structural meaning** in metric space.
- They provide **reference manifolds** for distance-based reasoning.
- They enable **prediction by structural continuation**, not regression.
- They decouple intelligence from raw signal memorization.

For observer-centric trajectories, KPFs represent **recurrent motion intentions or behaviors**, not precise paths.

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2. Definition: What Is a Trajectory Pattern Family?

A Trajectory Known Pattern Family is defined as:

A set of Trajectory IRs whose **L2 structural event sequences and L3 signatures are mutually close under DBM metric distance**, despite variation in L0/L1 signals.

Each family represents a **structural archetype**, not a single canonical curve.

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3. Design Principles

All trajectory pattern families must satisfy:

1. **Observer-Centric Validity**
   No family definition may rely on global coordinates or absolute scale.
2. **Structural Dominance**
   Membership is determined primarily by L2/L3 structure, not raw geometry.
3. **Mutation Closure**
   Small IR mutations must remain within the same family.
4. **Domain Reusability**
   Families should generalize across flight, animal motion, and robotics when structure matches.

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4. Core Trajectory Pattern Families

The following families form a **minimal yet expressive basis set**.

4.1 Approach Family

Structural Signature:

- Dominant radial decrease
- Low curvature
- Stable or accelerating speed

Interpretation:

- Target acquisition
- Pursuit
- Interception

4.2 Retreat / Escape Family

Structural Signature:

- Dominant radial increase
- Directional stability
- Possible burst acceleration

Interpretation:

- Evasion
- Threat avoidance
- Disengagement

4.3 Orbit / Loiter Family

Structural Signature:

- Alternating angular motion
- Near-zero net radial change
- Periodic or quasi-periodic structure

Interpretation:

- Surveillance
- Inspection
- Territorial behavior

4.4 Zigzag / Search Family

Structural Signature:

- Frequent heading reversals
- Moderate curvature oscillation
- Low net displacement

Interpretation:

- Search
- Exploration
- Uncertain pursuit

4.5 Glide / Cruise Family

Structural Signature:

- Low curvature
- Stable velocity regime
- Minimal acceleration events

Interpretation:

- Energy-efficient travel
- Patrol
- Transit

4.6 Hover / Stall Family

Structural Signature:

- Minimal radial and angular change
- High temporal density
- Structural stagnation

Interpretation:

- Observation
- Waiting
- Assessment

4.7 Sudden Maneuver Family

Structural Signature:

- High curvature spikes
- Abrupt acceleration polarity changes
- Short-duration dominance

Interpretation:

- Reactive avoidance
- Tactical adjustment
- Surprise response

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5. Composite and Hierarchical Families

Pattern families are **not flat**.

Examples:

- *Approach → Sudden Maneuver → Retreat*
- *Cruise → Orbit → Cruise*
- *Search → Approach → Capture*

Composite families are defined as **ordered compositions of base families**, preserving temporal causality.

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6. Family Boundaries and Membership

Membership is determined by:

- L3 signature distance below threshold
- Event sequence edit cost
- Duration ratio similarity

Families have **soft boundaries** with confidence scores, not binary labels.

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7. Pattern Families and Prediction

Prediction in DBM proceeds as:

1. Identify nearest pattern families.
2. Evaluate continuation likelihoods within each family.
3. Generate candidate future IRs by **structural continuation**, not extrapolation.
4. Rank outcomes by distance, confidence, and risk.

Thus, prediction is **family-conditioned**, not purely time-series-based.

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8. Pattern Family Evolution

Known Pattern Families are **not static**:

- New families may emerge via clustering + validation.
- Existing families may split or merge.
- Rare patterns may be flagged as anomalies rather than new families.

Governance rules (future ITEM) control promotion and retirement.

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9. Cross-Domain Consistency

A key DBM advantage is that:

- A predator pursuit trajectory,
- A missile interception path,
- A robotic arm reaching motion

may belong to the **same structural family** when observer-centric IRs align.

This confirms that KPFs encode **structure, not semantics**.

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10. Relationship to Other DBM Components

Trajectory KPFs directly support:

- Structural indexing
- Metric search
- Risk-aware prediction
- Explanation chains ("why this prediction")

They do not replace physics or control models but **precede and guide them**.

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11. Scope and Non-Goals

Out of scope:

- Semantic labeling (e.g., "bird", "drone")
- Intent certainty claims
- Policy optimization

These may consume KPF outputs but are not part of this layer.

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12. Summary

This item establishes a formal Known Pattern Family system for observer-centric trajectories, completing the structural bridge from IR schema to DBM reasoning. Pattern families encode reusable motion intelligence, enabling prediction, explanation, and generalization across domains.

DBM-COT ITEM #222（中文）

标题

以观察者为中心的运动轨迹已知模式族（**Known Pattern Families**）

定位

本 ITEM 定义 DBM 时间序列结构智能体系中，面向观察者中心运动轨迹的已知模式族（KPF）。模式族是连接轨迹 IR 与下游预测、分析、解释的关键结构知识层。

模式族不是统计聚类，而是可解释、可变异、可复用的结构原型。

一、模式族在 DBM 中的角色

在 DBM 中，已知模式族承担以下职责：

- 固定结构意义；
- 提供度量空间参考骨架；
- 支持基于结构延展的预测；
- 避免对原始轨迹的记忆化依赖。

它们描述的是运动结构行为，而非精确路径。

二、定义：什么是轨迹模式族？

轨迹模式族是指：

在 L2 结构事件序列与 L3 签名层面上彼此接近的一组轨迹 IR，即便其底层信号存在差异。

每个模式族是一个结构原型族。

三、设计原则

所有模式族必须满足：

1. 观察者中心有效性
2. 结构主导而非几何主导
3. 变异闭包性
4. 跨领域可复用性

四、核心模式族（基础集）

4.1 接近族（Approach）

- 径向持续减小
- 曲率低
- 稳定或加速

含义：追逐、拦截、目标接近

4.2 远离 / 逃逸族（Retreat / Escape）

- 径向持续增大
- 方向稳定
- 爆发式加速

含义：规避、脱离威胁

4.3 盘旋 / 滞留族（Orbit / Loiter）

- 角向周期变化
- 径向近似守恒
- 周期或准周期结构

含义：侦察、巡视、领地行为

4.4 之字 / 搜索族（Zigzag / Search）

- 频繁方向反转
- 中等曲率震荡
- 位移效率低

含义：搜索、不确定追踪

4.5 滑行 / 巡航族（Glide / Cruise）

- 曲率低
- 速度稳定
- 加速度事件稀少

含义：巡航、节能移动

4.6 悬停 / 停滞族（Hover / Stall）

- 径向与角向变化极小
- 时间密集
- 结构停滞

含义：观察、等待、评估

4.7 突发机动族（Sudden Maneuver）

- 曲率与加速度突变
- 短时主导
- 结构不连续

含义：规避、战术调整

五、复合与层级模式族

模式族可以时间有序组合，例如：

- 接近 → 突发机动 → 远离
- 巡航 → 盘旋 → 巡航
- 搜索 → 接近 → 捕获

复合族保持因果顺序，不是简单拼接。

六、族边界与归属

- 基于 L3 距离阈值
- 事件编辑代价
- 持续时间比例

归属是软边界 + 置信度。

七、模式族与预测机制

DBM 的预测流程为：

1. 定位最近模式族；
2. 在族内评估可能延展；
3. 生成候选未来 IR；
4. 按距离、置信度、风险排序。

预测是结构条件化的。

八、模式族的演化

模式族可演化：

- 新族的发现
- 族的拆分 / 合并
- 异常模式的隔离

治理规则将在后续 ITEM 中定义。

九、跨领域一致性

同一结构族可同时适用于：

- 动物捕食轨迹
- 飞行器拦截路径
- 机器人到达动作

证明 DBM 处理的是结构而非语义。

十、与 DBM 其他模块的关系

模式族直接支撑：

- 结构索引
- 度量搜索
- 风险感知预测
- 解释链生成

十一、非目标

本层不处理：

- 实体语义识别
- 意图确定性判断
- 控制策略生成

十二、小结

本 ITEM 完成了观察者中心运动轨迹从 IR 规格到结构知识层的关键一步，为 DBM 在飞行、动物行为与机器人运动智能上的统一奠定了坚实基础。
