The Emergent Truth: From Declarative Simplicity to Conceptual Completeness

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Abstract

We begin with the simplest possible statements—e.g., distinguishing "something" (1) from "nothing" (0)—and observe how additional facts and constraints organically yield deep insights, like the Pythagorean theorem. This purely declarative logic, unburdened by any imperative "update steps," naturally extends beyond simple geometry: it applies just as well to baseball (runs, outs, stats) or quantum mechanics (wavefunction superposition, measurement). Rather than delving into domain-specific complexities, we highlight how the same universal "rulebook" of five declarative primitives—**Schema**, **Data**, **Lookups**, **Aggregations**, and **Lambda Calculated Fields**—effortlessly captures reality across very different fields, without resorting to specialized syntax or procedural code.

By exploring three illustrative domains—**triangleness**, **quantum walks**, and **baseball**—this paper shows that **emergent truths** arise simply from enumerated facts, relationships, and aggregator formulas, all living in a snapshot-consistent environment. We ultimately introduce the **Conceptual Model Completeness Conjecture (CMCC)** as the unifying framework behind these examples: once you grasp how each domain's logic is spelled out structurally (and never with "setScore()" or "collapseWavefunction()" calls), you can see how "truth" emerges purely from the lattice of defined facts. **No imperative steps required**—just a small handful of domain-agnostic building blocks that scale from basic geometry to advanced physics and real-world sports.

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1. Introduction: The Emergence of Truth

1.1 Purpose of This Paper

This paper offers a narrative demonstration of how a purely declarative modeling approach—free of any imperative "update" calls—lets us capture the logic of three seemingly distinct domains: basic geometry, baseball scoring, and quantum measurement. We rely on just five primitives (Schema, Data, Lookups, Aggregations, and Lambda Calculated Fields) that unify knowledge modeling across these domains. Rather than proving Turing-completeness or diving into domain-specific minutiae, we focus on the big picture: **why** enumerated facts and aggregator formulas are enough to uncover "theorems" like Pythagoras, "three outs end an inning," and quantum collapse.

1.2 Motivation: From "I Think, Therefore I Am" to Declarative Worlds

Philosophical questions about truth often begin with René Descartes's cornerstone statement: "I think, therefore I am." Simply by acknowledging that **something** exists rather than nothing, we introduce the binary notion of presence (1) versus absence (0). Remarkably, this elementary distinction—1 vs. 0—can bootstrap an entire conceptual universe:

1. **Bits**: Once we establish 1 and 0, we can form binary strings.
2. **Numbers**: Strings of bits can represent numeric values.
3. **Coordinates**: We map these numbers into positions (x, y, etc.) and define points.
4. **Shapes**: By declaring points and the relationships among them, geometric structures "emerge," leading us straight to properties like angles and distances.

No one ever calls a function like `CreateTriangle()`; we simply **declare** that three points are connected, and a triangle necessarily appears in the conceptual space. From these connections alone, we inevitably reach geometry's famous result: the Pythagorean theorem. Thus, "theorems" arise from enumerated facts and constraints, not from stepwise procedures.

1.3 From Geometry to Baseball (and Beyond)

Having illustrated how binary facts yield geometric results, we then show how the same declarative mindset applies to domains that **seem** procedural, such as:

- **Baseball**: A sport that appears full of stepwise increments—runs, outs, innings—but which can just as easily be modeled by declaring events (`RunEvent`, `OutEvent`) and letting aggregator formulas compute the scoreboard.
- **Quantum Walk**: Where wavefunction superposition and measurement typically imply "collapsing" code routines. Instead, we treat them as data and constraints, allowing aggregator logic to handle amplitude distributions and measurement outcomes.

By comparing geometry, baseball, and quantum mechanics in one unified story, we highlight that no specialized DSL or imperative logic is needed. Instead, enumerating domain facts in JSON (or any data format) combined with aggregator fields can deliver the "magic" of emergent truths—be they Pythagoras's theorem, a final score, or a collapsed wavefunction.

2. Starting at Zero: Something versus Nothing

When we say "something exists," we tacitly admit there's a distinction between **presence** (1) and **absence** (0). This binary viewpoint forms the bedrock upon which all further logic stands.

2.1 Binary as the Declarative Foundation

1. **Defining Bits**: We start by asserting that 1 denotes existence and 0 denotes non-existence.
2. **Binary Representation**: A sequence of such bits is recognized as a valid representation for higher-level concepts—like integers, floats, or any enumerated code.

Hence, an essential truth emerges by definition: "Numbers are declaratively represented using binary."

2.2 Constructing a Conceptual Space

Once we have numbers, it's natural to **map** these values into coordinates:

1. **Numerical Coordinates**: We declare that two numbers (x, y) define a point in a conceptual (e.g., Cartesian) space.
2. **Points, Not Procedures**: We don't run a function "makePoint(…)"; we simply record that (x, y) is a point. That declaration alone is enough for a declarative system to recognize the point's existence.

2.3 Emergence of Geometric Structures

From these points, lines and polygons appear as logical consequences:

- **Lines**: Connecting two points yields a line segment. Its length, direction, or angles with other segments follow automatically from aggregator formulas.
- **Triangles**: Declaring a third point connected to the previous two creates a closed shape with three edges. A final aggregator clarifies the shape as a "triangle," complete with an angle sum of 180°.

2.4 Right Triangles Appear

Refining these facts, we add:

"If one internal angle is 90°, the shape is called a right triangle."

Now a hypotenuse emerges as the longest side opposite that angle. We label it c, with the other sides a and b. Again, no function calls—just structured facts about angles and side lengths.

2.5 The Pythagorean Theorem as an Emergent Fact

From the preceding constraints, $a^2 + b^2 = c^2$ becomes unavoidable. Nothing in the data instructs the system to "use Pythagoras"; rather, once a triangle is declared right-angled, aggregator logic that measures lengths from coordinates will **necessarily** reveal the Pythagorean relationship. Any contradictory assertion (like forcing $a^2 + b^2 \neq c^2$ in a right triangle) yields an inconsistency. Thus, Pythagoras exemplifies how powerful truths can surface naturally in a declarative environment.

3. Building a Conceptual Universe: Points, Lines, Shapes

Binary-encoded coordinates let us place any number of points in a 2D (or higher) space. Once we declare enough points, lines, and angles, the entire world of Euclidean geometry unfolds—without writing a single imperative routine like "drawShape()" or "computeAngle()."

3.1 Mapping Bits onto Coordinates

- **Numbers as Data**: Each coordinate value is just a bitstring that the system stores as "this is the x-part, this is the y-part."
- **Declarative Syntax**: We label `(x, y)` as a `Point`, letting aggregators handle any resulting lengths or angles.

3.2 From Points to Shapes

- **Line Segments**: Indicate that two points are "connected," and a line segment emerges. The system can track length and direction through aggregator formulas like distance calculations.
- **Angles**: With multiple connected segments, aggregator constraints define angles at the intersection point. If an angle measures 90°, the data tags it as a "right angle."

3.3 Triangles, Quadrilaterals, and Beyond

Expanding from two or three connected points to four or more leads us to quadrilaterals, polygons of n-sides, and so on:

- **Classification**: Aggregators can classify shapes (e.g., triangles vs. rectangles) by checking edge counts and angle values.
- **Dimensional Extension**: Extending to 3D (adding a z-value) or higher dimension is equally straightforward—simply store extra coordinates and let aggregator formulas do the rest.

All these structures are discovered by enumerating consistent data, not by imperative geometry calls.

3.4 Preview of the Same Logic in Baseball

This same principle—declaring facts, letting aggregators yield higher-level truths—applies seamlessly in **non-geometric** domains like baseball. Instead of angles and edges, we have:

- **RunEvent** and **OutEvent** records, referencing which team or inning they belong to.
- **Aggregators** for total runs and outs, automatically updating a "score" or signaling "three outs."

We'll see that, as in geometry, "no function `incrementScore()` is required." The aggregator-based approach unifies geometry, baseball, and even quantum mechanics under one declarative framework.

3.5 Conclusion of the Foundational Layer

By this point, we have:

1. A binary building block enabling numeric representation,
2. A method to declare points and shapes purely by storing data and constraints,

3. A proven pattern of "inevitable facts" emerging once we fix consistent relationships (e.g., the Pythagorean theorem).

With these fundamentals in hand, we now pivot to more "procedural-seeming" domains—starting with baseball—to highlight just how universal the declarative approach can be.

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4. Emergent Geometry: No "Theorem," Just Constraints

Having introduced lines and polygons, we now see that many "theorems" from classical geometry are actually **inevitable facts**—provided we **declare** a consistent set of relationships (like "three edges, one angle at 90°," etc.). None of these outcomes are coded or computed step by step; they naturally **arise** from the constraints.

4.1 Listing the Facts: "Three Angles," "Sum = 180°," "Right Triangle"

For a **triangle**, these basic facts become aggregator definitions:

- **Angle Count**: "Number of internal angles = 3."
- **Angle Sum**: "Sum of internal angles = 180°."
- **Right Triangle**: "If one angle = 90°, label the shape 'right triangle'."

In a typical geometry curriculum, you might see an entire proof dedicated to angle sums. Here, it's simply encoded as a constraint in the aggregator logic—**no** separate proposition or lemma required.

4.2 "Hypotenuse," "Legs," and Observations That Appear Without "Proof"

Once you declare a triangle to be "right-angled," further labels or definitions follow suit:

- **Hypotenuse**: The aggregator that locates the longest side automatically identifies it as "c."
- **Legs**: The other two sides, typically labeled "a" and "b," are recognized by an aggregator or a "lambda calculated field" (e.g., "IF side.length < hypotenuse THEN side is a leg").

Observe that these are still facts, not commands: The system "knows" which side is longest, so the notion of "hypotenuse" is forced by the constraints, not by an explicit assignment.

4.3 The Pythagorean Relationship as an "Inevitable Fact"

Here we arrive at one of geometry's crown jewels, but from a purely **constraint-based** vantage. Once an aggregator recognizes a right triangle, the squared lengths of the legs and hypotenuse automatically satisfy $a^2+b^2=c^2$. Because this relationship *cannot* be contradicted without invalidating prior definitions (angles, side lengths, etc.), it appears as a **logical necessity**—not a manually entered rule. For clarity:

- **No "Theorem"**: We never typed "theorem Pythagoras."
- **No "Proof"**: We never stepped through a proof in the classic sense.
- **Only Declarative Constraints**: We enumerated angles, identified a right angle, recognized a longest side, and the aggregator formulas forced the outcome.

This underscores the emergent nature of geometry in a purely declarative model: once you set the shape and angle constraints, the Pythagorean theorem is *unavoidable*.

4.4 The Role of Consistency: Why Contradicting the Fact List Gets Harder

If any newly introduced "fact" (e.g., "sum of angles = 200°" for a Euclidean triangle) conflicts with these aggregator rules, the system simply flags an inconsistency—there's no feasible way to reconcile the new claim with the existing definitions. As more facts accumulate, contradictions become both more likely if you deviate and *more obviously impossible* unless you correct the original statement. This is how purely declarative systems **enforce** geometry: not by code, but by unyielding structural consistency.

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5. Extending the Same Logic to Broader Domains

Up to this point, we've illustrated how geometry emerges from enumerated facts about points, lines, and angles. But the power of this approach shines even brighter when we step outside of classical geometry and into domains people typically describe as "procedural." Here, we show that baseball scoring and quantum phenomena can be framed **exactly** the same way.

5.1 Baseball: Runs, Outs, and Score Without "SetScore()"

In a typical baseball simulation, you might see code like `incrementRuns(team, 1)` or `setOuts(outs + 1)`. A purely declarative approach replaces these imperative steps with **events** and **aggregator fields**:

- **RunEvent**: A factual record stating, "This run occurred in the 3rd inning, referencing player X."
- **OutEvent**: Another factual record, "This out occurred in the bottom of the 5th inning, referencing player Y."

From these facts alone, aggregator formulas compute totals—runs per team, outs per inning—and *enforce* baseball's transitions (e.g., three outs end an inning) by referencing these aggregated values. No single function call says "switch innings now." The scoreboard effectively updates itself through constraints like:

- "inning ends if `OUTS` >= 3"
- "game ends if `inning` >= 9 and `runs_teamA != runs_teamB`"

Just as we never wrote a "theorem" in geometry, we never write `updateScore()` in baseball. The aggregator logic reveals the game state from the raw facts of events.

5.2 Quantum Physics: "Wavefunction Collapse" Without "Collapse()"

At first glance, quantum phenomena (superposition, interference, measurement) seem too esoteric for the same method that handled triangles and baseball. Yet the core principle is identical: once we store amplitude data for a wavefunction, aggregator formulas can track interference patterns, probabilities, or partial states.

- **Wavefunction**: A record storing amplitude values at each possible location or state.
- **MeasurementEvent**: A data record that references a specific wavefunction plus a measurement outcome.

Similar to baseball, no code calls `collapseWavefunction()`. Instead, aggregator constraints ensure that the wavefunction's superposed amplitudes "reduce" to the measured outcome once the event is declared. Any contradictory measurement outcome (e.g., measuring spin-up and spin-down simultaneously) flags an inconsistency. Thus, quantum collapse is just as declarative as "triangle side lengths" or "baseball scoring."

5.3 Any Domain: From Edges and Angles to Observers and Particles

The key insight is that **Schema, Data, Lookups, Aggregations, and Lambda Calculated Fields** form a universal basis for *all* manner of knowledge. Whether describing a triangle or a wavefunction, you define factual entities (e.g., edges, angles, or amplitude distributions) and aggregator-driven relationships (e.g., "sum angles to 180°," or "probabilities must total 1"). The "rest" simply *happens* by structural necessity.

This approach reveals that "procedural" illusions—like incrementing runs or forcing wavefunction collapse—are in fact emergent aggregator outcomes. Once enough domain data is declared, any higher-level rule or "theorem" you normally would code is simply an inevitable result of the constraints.

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6. A Snapshot-Consistent Environment: What It Means

Everything we've described—triangles, baseball events, quantum wavefunction states—relies on a core principle: **all facts and aggregator results exist within a single, consistent snapshot** of the data. In other words, at any moment, the system's declared facts and derived fields must align with each other, forming a coherent picture of "what is true right now."6.

6.1 Declarative vs. Imperative: The Fundamental Distinction

An **imperative** approach typically involves updating variables in a sequence:

1. `score = score + 1`
2. If `outs == 3`, then move to next inning
3. etc.

By contrast, a **declarative** approach never "runs" these steps; it merely **states** the relationship:

- "`score` is the sum of all RunEvents referencing this team."
- "When the aggregator `outs` reaches 3, the inning is finished."

Nothing *executes* at runtime to push these states forward; the aggregator logic itself ensures that whenever you look at the data snapshot, each aggregator field has the correct derived value, and each constraint is enforced.

Imperative vs. Declarative

Below is a compact table illustrating how each example domain typically uses imperative logic and how it transforms under a declarative, CMCC-based approach:

Domain	Imperative Approach	Declarative (CMCC) Approach
Geometry	- Manually compute angles or apply theorems via stepwise proofs	- Declare points, edges, angles as data

	- `computeAngles()` or `provePythagoras()` calls	- Aggregators (like `sum_of_angles`) and constraints automatically yield Pythagoras, etc.
Baseball	- Procedural calls like `incrementScore(team)`	- Declare `RunEvent` and `OutEvent` facts
	- "End inning if outs == 3" coded imperatively	- Aggregators compute total runs, outs, and handle inning transitions through constraints
Quantum	- Functions like `collapseWavefunction()` in simulation steps	- Declare amplitude distributions and `MeasurementEvent`
	- Imperative loop over states or measurement routines	- Aggregator constraints unify superposition and collapse (no `collapse()` call needed)

In each domain, the CMCC approach replaces explicit function calls and stepwise updates with a small set of declarative primitives (schema, data, lookups, aggregations, and lambdas). "Truth" then emerges from consistent snapshots of these facts and constraints—no manual procedure required.

6.2 Why Aggregators and Constraints Capture All Necessary Logic

Aggregators (like `SUM`, `COUNT`, or `MAX`) plus conditional constraints can encode everything from "triangle angle sums" to "wavefunction probability amplitudes." The key is:

- **No partial updates**: You never see a half-updated state. Either the aggregator formula has enough facts to compute a consistent result, or it flags an inconsistency.
- **No hidden side effects**: Each aggregator's output depends solely on the underlying data, so changes to any input fact are reflected automatically.
- **Universality of Conditions**: If you can define a domain rule as a function of existing facts—be it "angles must sum to 180°" or "the total probability must be 1"—you can express it as a constraint or aggregator.

So long as the system can store these relationships and maintain snapshot consistency, you never need manual procedures like `recalculateAngles()` or `collapseWavefunction()`.

6.3 The Tension Between "Data" and "Derived State"

In traditional architectures, you often keep "data" (e.g., table rows) and "derived state" (aggregations, indexes, caches) as separate layers, sometimes leading to race conditions or stale values. A **snapshot-consistent** environment folds them into one conceptual domain: whenever new facts are introduced, aggregator fields update *in the same snapshot*. This ensures:

1. **Atomicity**: Either all facts and aggregator results are committed together, or none are.
2. **Consistency**: Contradictions are caught immediately, rather than lurking in partial states.
3. **Isolation & Durability**: Other processes see only the final stable outcome, not an intermediate stage.

For geometry, this means you can't "partly" declare a triangle that only has two edges. For baseball, you won't see a partial increment of runs without also updating outs if needed. For quantum, you won't measure half a collapsed state. Everything is always consistent in the final committed snapshot.

6.4 Handling Contradictions and Flagging Errors

In any purely declarative system, data might arrive that conflicts with existing facts or aggregator constraints. When this occurs in a CMCC environment, the system flags an inconsistency rather than applying partial or contradictory updates.

Example: Invalid Triangle Angle Sum

1. Suppose we have a polygon declared with `edge_count = 3`, indicating it's a triangle.
2. The angle aggregator is constrained by "sum of angles = 180°" for Euclidean geometry.
3. If a user or process mistakenly declares an angle set of `[90°, 60°, 50°]`, the aggregator tries to enforce `90 + 60 + 50 = 200`, which contradicts the "triangle sum = 180" rule.

When the snapshot is evaluated, the system detects an unresolvable conflict—your aggregator logic or constraints effectively produce an error. A simple diagnostic message might look like this:

pgsql

CopyEdit

```
ERROR: Aggregator conflict on Polygon#123

 - Declared as triangle (edge_count=3), implies sum_of_angles=180

 - Actual angles declared: [90, 60, 50], sum=200

 - Contradiction: "Triangle angle sum mismatch"

Transaction aborted. Please correct the angle data or remove the triangle
constraint.
```

How Contradictions Are Resolved

- **No partial commits**: If the system enforces snapshot consistency, it refuses to finalize the new or updated facts until the conflict is resolved.
- **Possible user or system action**: The user can adjust angles, change `edge_count`, or remove contradictory data.
- **End result**: The committed snapshot always remains consistent, and invalid data is never allowed to "coexist" in partial form.

This same pattern applies in baseball ("four outs in one half-inning" triggers a conflict) or quantum ("simultaneous contradictory measurement outcomes"). By requiring all new facts to align with existing aggregators, the system ensures emergent truths remain globally consistent.

7. Revealing the Punchline: The CMCC

Having walked through geometry, baseball, and quantum domains, we can now articulate the **Conceptual Model Completeness Conjecture (CMCC)**: *Any domain's entire logic can be captured by enumerating facts, relationships, aggregator formulas, and conditional fields within a snapshot-consistent model—requiring no additional imperative instructions.*

7.1 A Universal Rulebook for Schema (S), Data (D), Lookups (L), Aggregations (A), and Lambdas (F)

CMCC stands on **five** declarative primitives:

1. **Schema (S)**: Defines each entity type (e.g., "Polygon," "Angle," "BaseballGame," "Wavefunction") and its fields.
2. **Data (D)**: Concrete records or events (e.g., "Angle with 53°," "RunEvent in the 3rd inning," "MeasurementEvent at time t").
3. **Lookups (L)**: References linking records (e.g., "this Edge belongs to that Polygon," "this measurement references that wavefunction").
4. **Aggregations (A)**: Summations, counts, maxima, or derived metrics computed purely from data/lookups (e.g., "edge_count = COUNT(this.edges)").
5. **Lambda Calculated Fields (F)**: Declarative constraints or if-then expressions that define how domain rules apply. Example: "IF angle_degrees = 90, THEN shape_type = right_triangle."

Crucially, none of these primitives require specifying *how* to update or iterate. The runtime enforces consistency for each aggregator or condition whenever the underlying data changes.

7.2 Surprise: You've Already Been Using the Logic of the CMCC All Along

In exploring geometry, baseball, and quantum examples, we've effectively been *using* CMCC primitives—without calling them by name:

- **Schema & Data**: We introduced "polygon," "run event," "wavefunction."
- **Lookups**: We said "three points reference each other as edges."
- **Aggregations**: We used "sum of angles," "count of runs," "maximum amplitude."
- **Lambda Fields**: We had "if angle = 90°, then it's a right triangle," "if outs = 3, the inning is done," "if measurement is declared, collapse wavefunction to the measured state."

So the "magic" you witnessed—Pythagoras appearing unbidden, baseball scoreboard updates with no `setScore()`, quantum collapse with no `collapseWavefunction()`—isn't magic at all. It's the natural consequence of enumerating domain constraints in a purely declarative schema.

7.3 Tying It All Together: Why No Single Step in the Process Required a Theorem

The standard approach to geometry or scoring or quantum measurement would be to define a function for each special step ("prove Pythagoras," "increment runs," "invoke wavefunction collapse"). But if you adopt CMCC's perspective, each domain property is simply a forced outcome of the aggregator definitions and constraints you've declared. Because no theorem or stepwise procedure is needed, **truth emerges** from the structure itself.

8. Discussion & Implications

Now that we've framed geometry, baseball, and quantum mechanics under one declarative umbrella, let's consider how this approach affects broader domains—like AI, enterprise data management, and multi-domain integrations.

8.1 The Power of Emergent Meaning in Knowledge Modeling

In typical data systems, domain logic is scattered in imperative code. By consolidating logic in aggregator formulas and constraints, you gain:

- **Transparency**: Any domain rule is discoverable as a schema or aggregator definition, rather than hidden in function calls.
- **Maintainability**: Changing a domain rule (e.g., adjusting baseball's "mercy rule" threshold) is as simple as editing a single aggregator or lambda field.
- **Interoperability**: Because no specialized syntax is needed, it's trivial to integrate multiple domains—like geometry plus quantum or baseball plus economics—by merging or referencing each other's aggregator fields and lookups.

8.2 Implications for Software, Data Management, and AI Reasoning

Consider the impact on large-scale software:

1. **Reduced Complexity**: You eliminate a raft of "update" or "synchronization" procedures and unify them into a small set of aggregator definitions.
2. **Clear Auditing**: Every emergent outcome (like a final score or collapsed wavefunction) can be traced back to the factual records that drove it—no hidden side effects.
3. **AI Transparency**: Declarative knowledge bases align well with explainable AI, since derived conclusions (like "why is this shape a triangle?") are pinned to aggregator logic, not black-box code.

8.3 Combining Many "Mini-Fact" Domains into a Single Declarative Universe

Finally, because each domain is just a **Schema + Data + Aggregators** package, it's straightforward to connect them. Imagine referencing a geometry shape inside a quantum wavefunction domain, or overlaying baseball stats with economic data. As long as each domain expresses constraints purely declaratively, their aggregator fields can coexist, giving you a "bigger universe" of emergent truths with minimal friction.

In the next (and final) section, we'll summarize how the same structural approach leads to a stable, consistent representation of "truth," even across wide-ranging domains—and where we can go from here.

8.4 Addressing Querying and Retrieval

A purely declarative model is only as useful as our ability to query and retrieve the emergent facts it encodes. In practical terms, two highly accessible platforms for building CMCC models are **Baserow** and **Airtable**, each offering a JSON-based meta-model API. In such systems:

- **Schema Access**
  You can retrieve the entire "rulebook" (Schema, Data, Lookups, Aggregations, Lambdas, Constraints) in JSON form. This ensures that both human developers and programmatic agents can inspect every

declared constraint or aggregator formula on demand.

- **Snapshot-Consistent Data**
  With each commit or change, the data and all derived aggregator fields remain transactionally aligned. Any valid query against that snapshot sees a fully coherent state.

- **Template-Based Generation**
  For lightweight transformations, **Handlebars**-style templates can render the JSON data into user-facing formats (reports, HTML, etc.). At larger scales, any ACID-compliant datastore (e.g., SQL Server, MySQL, PostgreSQL) can serve as the engine beneath these declarative objects, guaranteeing the same snapshot consistency.

Thus, retrieval becomes straightforward: "facts in, queries out." When you fetch data from the aggregator fields or derived states, you inherently observe the entire truth declared at that moment—no extra code to "update" or "synchronize" anything.

8.5 Implementation & Performance Considerations

Finally, it's important to emphasize that **CMCC is just the universal "rulebook"**: it defines how domains and aggregators interlock to produce snapshot-consistent truths. The **runtime engine** that enforces these declarative constraints can be written in a variety of ways, each conforming to standard best practices for scalability and performance:

- **SQL Triggers & Materialized Views**: One could map aggregator formulas onto materialized views updated transactionally or use ACID-compliant triggers to enforce constraints.
- **Distributed Databases**: In large-scale or high-availability systems, aggregator logic might be partitioned or sharded, with a commit-phase consistency check ensuring data is never partially updated.
- **Real-Time Responsiveness**: For time-series and streaming data, incremental aggregator updates can be pipelined, so the next snapshot always reflects new facts.
- **Optimizations & Caches**: Indexes, caching layers, or parallel processing can reduce overhead in recomputing aggregations, even at massive scale.

The key point is that **CMCC's declarative model is independent of the actual physical implementation**: as long as the runtime maintains snapshot consistency and enforces the aggregator logic atomically, developers are free to employ all industry-standard techniques for high-performance, real-time, or distributed computing.

8.6 Positioning Relative to Known Approaches

It's worth noting that **logic programming** (e.g., Prolog, Datalog) and **semantic-web** frameworks (RDF, OWL) also use declarative statements of facts and rules rather than imperative code. However, typical triple-store or ontology systems do not natively support aggregations and lambda-style calculations as first-class constructs; those often require separate SPARQL queries or specialized reasoners. Meanwhile, functional programming excels at pure functions and immutability but does not inherently define a single, snapshot-consistent data store with aggregator constraints. **CMCC** merges the two models: (1) a fact-based representation of entities and relationships, and (2) built-in aggregator and lambda fields all enforced within an atomic snapshot. This synthesis, coupled with consistent transaction semantics, turns out to be remarkably powerful for representing logic across multiple domains—without "sidecar" scripts or partial updates.

The underlying philosophy of CMCC overlaps with logic/ontology frameworks such as **RDF/OWL**, **GraphQL schemas**, or classical **relational** modeling. However, most of these systems lack three critical features that CMCC insists upon:

1. **Native Aggregations**
   CMCC treats sums, counts, min/max, means, or more advanced rollups as first-class, snapshot-consistent fields. By contrast, RDF/OWL and typical knowledge-graph systems often need external "sidecar" processes (SPARQL queries, reasoner plugins) to compute or store aggregates.

2. **Lambda Functions**
   CMCC includes "L" or "Lambda Calculated Fields" for if-then or more functional logic—again stored within the same declarative structure, rather than in a separate code layer.

3. **Strict Snapshot Consistency**
   Many existing frameworks either rely on asynchronous updates or do not guarantee that all derived fields are in sync at every moment. In CMCC, every aggregator is always consistent with the data in one atomic snapshot.

Hence, CMCC does not require external scripts, triggers, or imperative "sidecars." By embedding aggregations and functional fields alongside the raw data, it keeps everything in a single, consistent knowledge lattice. Other papers in this series delve into deeper comparisons, but these are the key differentiators for now.

8.7 Expanding Multi-Domain Integration

Throughout the paper, we noted that geometry, baseball, and quantum mechanics can co-exist under a single rule set. A more realistic illustration might blend **economic** factors (e.g., ticket revenue, city engagement) with the performance of a hometown baseball team:

- **Home-Win Economic Impact**
   Suppose we declare a "CityEconomics" entity that aggregates foot traffic, local business revenue, and intangible morale. Each "home game" event references the same aggregator fields, so when the hometown team wins multiple games in a row, we can observe a correlated rise in local economic metrics—all within the same snapshot.

- **Simple Declarative Rule**
   "IF `winStreak >= 5` THEN `CityEconomics.moraleRating = +0.1`," purely as a lambda or aggregator constraint. No imperative "updateCityMorale()" is required.

This approach can extend indefinitely. As long as each domain expresses its rules and relationships using the same five primitives (S, D, L, A, F) in a consistent snapshot environment, the data merges seamlessly—and new emergent cross-domain truths may appear.

8.8 Exploring Large-Scale or Real-World Systems

Finally, the CMCC approach scales in principle to any real-world environment, because the model only says **what** is true, not **how** to make it so. Some practical observations:

- **Implementation Freedom**
  "Magic mice in assembler code" (or any other solution) can handle the runtime logic. So long as the aggregator formulas and constraints are satisfied at commit time, a system can be distributed, multi-threaded, or specialized for big data.

- **Best Practices Still Apply**
  You can partition or shard large tables, use caching layers, parallelize aggregator computations, and so on. From the CMCC perspective, these are purely optimizations: the end result must remain snapshot-consistent with the declared rules.

- **Physical Reality as the Runtime**
  For advanced domains like quantum mechanics or real-time scientific experiments, one might say the laws of nature "run" the system. The CMCC model then describes the data we gather (measurement events, wavefunction states) without prescribing how the physical process actually executes.

Thus, whether you have a small local dataset in Airtable or a petabyte-scale system in a global datacenter, the essential declarative logic remains the same. **CMCC** is simply the universal rulebook, not the runtime engine.

---

9. Conclusion: Structure as Truth

We set out to show how three very different domains—basic geometry, baseball, and quantum phenomena—can be modeled without a single imperative "update" call. Instead, these domains unfold purely from enumerated facts, references, and aggregator definitions, all guaranteed consistent by a snapshot-based approach.

9.1 The Strength of Fact Piling: Incoherence Becomes Impossible

Because each new fact or constraint must integrate harmoniously into an existing snapshot, the system naturally prevents contradictions or incoherent intermediate states. For geometry, you cannot have a "triangle" with four edges. For baseball, you cannot have four outs in the same half-inning. For quantum physics, you cannot measure mutually exclusive outcomes simultaneously. The principle of snapshot consistency ensures that all derived truths (angle sums, scoreboard tallies, collapsed wavefunctions) remain consistent with the entire web of declared facts.

As more facts accrue, the "cost" of introducing false or contradictory statements grows: the system will simply flag the inconsistency. This mechanism neatly inverts the typical anxiety over "edge cases" or "corner conditions" in procedural code, since each aggregator and constraint stands as an explicit guardrail for domain coherence.

9.2 Future Directions: New Domains, Larger Ecosystems, and Handling Contradictions

The declarative perspective presented here sets the stage for an impressive array of future work. A few examples include:

1. **Larger, Cross-Domain Ecosystems**
   - Combining baseball with economic modeling or linking quantum mechanical events to a geometry-based design. Because each domain's logic is declared in the same aggregator style, cross-domain queries and insights emerge naturally.

2. **Concurrency and Distributed Systems**
   - Exploring how snapshot consistency scales across distributed databases. If each node commits facts and aggregations transactionally, one could maintain a globally coherent knowledge base of indefinite size.
3. **Handling Partial Inconsistencies or Contradictions**
   - Investigating how "soft constraints" or partial aggregator definitions might allow for uncertain or evolving data (common in real-world AI systems). This might involve merging multiple snapshots or identifying domains where incomplete facts must be later reconciled.
4. **Turing Completeness and Halting**
   - Although this paper did not delve into the formal completeness proofs or the halting problem, readers may reference parallel works that show how a purely declarative aggregator system can, in principle, simulate universal computation. The boundaries and limitations (e.g., Gödelian self-reference) are ripe areas for continued investigation.

Ultimately, if the Conceptual Model Completeness Conjecture (CMCC) holds as we scale up, one might imagine an increasingly universal framework in which all computable truths—be they mathematical, athletic, or physical—are captured by the same five declarative primitives in a single snapshot-consistent environment.

References & Acknowledgments

Below is a consolidated list of works cited throughout the paper, spanning foundational philosophy, mathematics, physics, and the broader context of declarative modeling.

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7. **Everett, H. (1957)**
   "'Relative State' Formulation of Quantum Mechanics." *Reviews of Modern Physics,* 29, 454–462.

8. **Wigner, E. (1961)**
   "Remarks on the Mind-Body Question." In I. J. Good (Ed.), *The Scientist Speculates,* Heinemann.

For practical examples, code, and JSON-based domain definitions (geometry, baseball, quantum walks), please visit the project's GitHub repository:
github.com/eejai42/conceptual-model-completeness-conjecture-toe-meta-model

Appendices

Appendix A: Example Declarative Statements (Geometry)

Sample aggregator definitions and field constraints illustrating how "sum of angles" or "isRightTriangle" can be purely declared, with no further code.

```
{
  "id": "CMCC_ToEMM_TriangleMinimal",
  "meta-model": {
    "name": "Minimal Triangleness Demo",
    "description": "Demonstration of a polygon model that checks for 3-edge polygons,
                    right angles, etc. using only a tiny set of aggregator formulas.",
    "version": "v1.0",
    "nickname": "triangle_demo",
    "schema": {
      "entities": [
        {
          "name": "Edge",
          "description": "A simple edge record. (No advanced geometry;
                          just a placeholder.)",
          "fields": [
            {"name": "id","type": "scalar","datatype": "string","primary_key": true},
            {"name": "label","type": "scalar","datatype": "string",
                     "description": "Optional name or label for the edge."},
            {"name": "polygon_id","type": "lookup","description": "Points back to
                     which polygon this edge belongs.","target_entity": "Polygon"}
          ],
          "lookups": [],
          "aggregations": [],
          "lambdas": [],
          "constraints": []
        },
        {
          "name": "Angle",
          "description": "Represents a single angle (in degrees)
                          belonging to a polygon.",
          "fields": [
            {"name": "id","type": "scalar","datatype": "string","primary_key": true},
            {"name": "angle_degrees","type": "scalar","datatype": "float",
                     "description": "The angle measure in degrees."},
            {"name": "polygon_id","type": "lookup","description": "Which polygon
                     this angle belongs to.","target_entity": "Polygon"}
          ],
          "lookups": [],
          "aggregations": [],
```

```
        "lambdas": [],
        "constraints": []
    },
    {
      "name": "Polygon",
      "description": "A polygon with edges and angles. We'll check if
                      it's a triangle, if it has a right angle, etc.",
      "fields": [
        {"name": "id","type": "scalar","datatype": "string",
                      "primary_key": true},
        {"name": "label","type": "scalar","datatype": "string",
                        "description": "Optional name for the polygon."}
      ],
      "lookups": [
        {
          "name"          : "edges"                               ,
          "target_entity" : "Edge"                                ,
          "type"          : "one_to_many"                         ,
          "join_condition": "Edge.polygon_id = this.id"           ,
          "description"   : "All edges that form this polygon."
        },
        {
          "name"          : "angles"                              ,
          "target_entity" : "Angle"                               ,
          "type"          : "one_to_many"                         ,
          "join_condition": "Angle.polygon_id = this.id"          ,
          "description"   : "All angles belonging to this polygon."
        },
        {
          "name"          : "angle_degrees"                       ,
          "target_entity" : "this"                                ,
          "type"          : "one_to_many"                         ,
          "join_condition": "this.angles.angle_degrees"           ,
          "description"   : "An array of the angles of a triangle."
        }
      ],
      "aggregations": [
        {"name": "edge_count","type": "rollup","description": "Number of edges
                    in this polygon.","formula": "COUNT(this.edges)"},
        {"name": "angle_count","type": "rollup","description": "Number of angles
                    in this polygon.","formula": "COUNT(this.angles)"},
        {"name": "largest_angle","type": "rollup","description": "The maximum
                    angle measure among angles.",
                    "formula": "MAX(this.angle_degrees)"},
```

```
                {"name": "sum_of_angles","type": "rollup","description": "Sum of all
                        angle measures in degrees.",
                        "formula": "SUM(this.angle_degrees)"},
                {"name": "is_triangle","type": "rollup","description": "True if the
                        polygon has exactly 3 edges.",
                        "formula": "EQUAL(this.edge_count, 3)"},
                {"name": "has_right_angle","type": "rollup","description": "True if
                        any angle == 90.","formula": "CONTAINS(this.angle_degrees, 90)"},
                {
                    "name"        : "shape_type",
                    "type"        : "rollup",
                    "description": "Naive categorization based on edge_count:
                                    3 => triangle, 4 => quadrilateral, else other.",
                    "formula"    : "IF( EQUAL(this.edge_count,3), 'triangle',
                                    IF(EQUAL(this.edge_count,4),'square','polygon') )"
                }
              ],
              "lambdas": [],
              "constraints": []
            }
          ],
          "data": {"Edge": [],"Angle": [],"Polygon": []}
        }
      }
    }
```

And this is the code that is derived directly from it:

```python
"""
Auto-generated Python code from your domain model.
Now with aggregator rewriting that references core_lambda_functions.
"""
import math
import numpy as np
from core_lambda_functions import COUNT, SUM, MAX, IF, CONTAINS, EQUAL

import uuid
import re

class CollectionWrapper:
    """A tiny helper so we can do something like: obj.someLookup.add(item)."""
    def __init__(self, parent_object, attr_name):
        self.parent_object = parent_object
        self.attr_name = attr_name
        if not hasattr(parent_object, '_collections'):
            parent_object._collections = {}
        if attr_name not in parent_object._collections:
            parent_object._collections[attr_name] = []
```

```python
    def add(self, item):
        self.parent_object._collections[self.attr_name].append(item)

    def __iter__(self):
        return iter(self.parent_object._collections[self.attr_name])

    def __len__(self):
        return len(self.parent_object._collections[self.attr_name])

    def __getitem__(self, index):
        return self.parent_object._collections[self.attr_name][index]


# Below are aggregator stubs not yet in core_lambda_functions:
def AVG(collection):
    """Placeholder aggregator: real logic not yet implemented."""
    # Could do: return sum(collection)/len(collection) if numeric
    return f"/* AVG not implemented: {collection} */"


def EXISTS(condition_expr):
    return f"/* EXISTS not implemented: {condition_expr} */"


def MINBY(expr):
    return f"/* MINBY not implemented: {expr} */"


def MAXBY(expr):
    return f"/* MAXBY not implemented: {expr} */"


def MODE(expr):
    return f"/* MODE not implemented: {expr} */"


def TOPN(expr):
    return f"/* TOPN not implemented: {expr} */"



# ----- Generated classes below -----

class Edge:
    """Plain data container for Edge entities."""
    def __init__(self, **kwargs):
        self.id = kwargs.get('id')
        self.label = kwargs.get('label')
        self.polygon_id = kwargs.get('polygon_id')

        # If any 'one_to_many' or 'many_to_many' lookups exist, store them as
            collection wrappers.
```

```python
class Angle:
    """Plain data container for Angle entities."""
    def __init__(self, **kwargs):
        self.id = kwargs.get('id')
        self.angle_degrees = kwargs.get('angle_degrees')
        self.polygon_id = kwargs.get('polygon_id')

        # If any 'one_to_many' or 'many_to_many' lookups exist, store them as
            collection wrappers.


class Polygon:
    """Plain data container for Polygon entities."""
    def __init__(self, **kwargs):
        self.id = kwargs.get('id')
        self.label = kwargs.get('label')

        # If any 'one_to_many' or 'many_to_many' lookups exist, store them as
            collection wrappers.
        self.edges = CollectionWrapper(self, 'edges')
        self.angles = CollectionWrapper(self, 'angles')

    @property
    def edge_count(self):
        """Number of edges in this polygon.
        Original formula: COUNT(this.edges)
        """
        return COUNT(self.edges)

    @property
    def angle_count(self):
        """Number of angles in this polygon.
        Original formula: COUNT(this.angles)
        """
        return COUNT(self.angles)

    @property
    def largest_angle(self):
        """The maximum angle measure among angles.
        Original formula: MAX(this.angle_degrees)
        """
        return MAX(self.angle_degrees)

    @property
    def sum_of_angles(self):
        """Sum of all angle measures in degrees.
        Original formula: SUM(this.angle_degrees)
        """
```

```python
        return SUM(self.angle_degrees)

    @property
    def is_triangle(self):
        """True if the polygon has exactly 3 edges.
        Original formula: EQUAL(this.edge_count, 3)
        """
        return EQUAL(self.edge_count, 3)

    @property
    def has_right_angle(self):
        """True if any angle == 90.
        Original formula: CONTAINS(this.angle_degrees, 90)
        """
        return CONTAINS(self.angle_degrees, 90)

    @property
    def shape_type(self):
        """Naive categorization based on edge_count: 3 => triangle, 4 => quadrilateral,
           else other.
        Original formula: IF( EQUAL(this.edge_count,3), 'triangle',
            IF(EQUAL(this.edge_count,4),'square','polygon') )
        """
        return IF( EQUAL(self.edge_count,3), 'triangle',
IF(EQUAL(self.edge_count,4),'square','polygon') )

    # Derived properties for 'target_entity': 'this'
    @property
    def angle_degrees(self):
        """An array of the angles of a triangle."""
        return [x.angle_degrees for x in self.angles]
```

Putting it into practice:

Triangle and Polygon Demo

This repository demonstrates a simple SDK for working with polygons, with a focus on triangles and their properties. The code uses a straightforward object model with properties that compute dynamically based on the shape's edges and angles.

Data Model Visualization

The following shows how data builds up as we progress through creating different polygons:

Creating an Empty Polygon

```python
polygon = Polygon()
```

Data State:

```json
{
  "Edge": [],
  "Angle": [],
  "Polygon": [
    {
      "edges": [],
      "angles": [],
      "edge_count": 0,
      "angle_count": 0,
      "angle_degrees": [],
      "largest_angle": null,
      "sum_of_angles": 0,
      "is_triangle": false,
      "has_right_angle": false,
      "shape_type": "polygon"
    }
  ]
}
```

Adding First Edge and Right Angle (90°)

```python
edge1 = Edge()
angle90 = Angle()
angle90.angle_degrees = 90   # Right angle
polygon.edges.add(edge1)
polygon.angles.add(angle90)
```

Data State:

```json
{
  "Edges": [{}],
  "Angles": [{ "angle_degrees": 90}],
  "Polygon": [
    {
      "edges": [{}],
      "angles": [{ "angle_degrees": 90 }],
      "edge_count": 1,
      "angle_count": 1,
      "angle_degrees": [90],
      "largest_angle": 90,
      "sum_of_angles": 90,
      "is_triangle": false,
      "has_right_angle": true,
      "shape_type": "polygon"
    }
  ]
}
```

Adding Second Edge and Angle

```python
edge2 = Edge()
angle53 = Angle()
angle53.angle_degrees = 53
polygon.edges.add(edge2)
polygon.angles.add(angle53)
```

Data State:

```json
{
  "Edges": [{}, {}],
  "Angles": [{ "angle_degrees": 90}, { "angle_degrees": 53}],
  "Polygons": [{
      "edges": [{}, {}],
      "angles": [{ "angle_degrees": 90 }, { "angle_degrees": 53 }],
      "edge_count": 2,
      "angle_count": 2,
      "angle_degrees": [90, 53],
      "largest_angle": 90,
      "sum_of_angles": 143,
      "is_triangle": false,
      "has_right_angle": true,
      "shape_type": "polygon"
    }
  ]
}
```

Creating a Triangle - Adding Third Edge and Angle

```
edge3 = Edge()
angle37 = Angle()
angle37.angle_degrees = 37
polygon.edges.add(edge3)
polygon.angles.add(angle37)
```

Data State:

```json
{
  "Edges": [{}, {}, {}],
  "Angles": [{ "angle_degrees": 90}, { "angle_degrees": 53}, { "angle_degrees": 37}],
  "Polygons": [{
      "edges": [{}, {}, {}],
      "angles": [{ "angle_degrees": 90 }, { "angle_degrees": 53 }, { "angle_degrees": 37 }]}],
      "edge_count": 3,
      "angle_count": 3,
      "angle_degrees": [90, 53, 37],
      "largest_angle": 90,
      "sum_of_angles": 180,
      "is_triangle": true,
      "has_right_angle": true,
      "shape_type": "triangle"
    }
  ]
}
```

Changing the Right Angle to 91° (No Longer Right)

```
# Modify the existing angle
angle90.angle_degrees = 91
```

Data State:

```
{
  "Edges": [{}, {}, {}],
  "Angles": [{ "angle_degrees": 91}, { "angle_degrees": 53}, { "angle_degrees": 37}],
  "Polygons": [{
      "edges": [{}, {}, {}],
      "angles": [{ "angle_degrees": 91 }, { "angle_degrees": 53 }, { "angle_degrees": 37 }]}],
      "edge_count": 3,
      "angle_count": 3,
      "angle_degrees": [91, 53, 37],
      "largest_angle": 91,
      "sum_of_angles": 180,
      "is_triangle": true,
      "has_right_angle": false,
      "shape_type": "triangle"
    }
  ]
}
```

Making a Square - Adding Fourth Edge and Angle

```
edge4 = Edge()
angle90b = Angle()
angle90b.angle_degrees = 90
polygon.edges.add(edge4)
polygon.angles.add(angle90b)
```

Data State:

```
  "Edges": [{}, {}, {}],
  "Angles": [{ "angle_degrees": 91}, { "angle_degrees": 53}, { "angle_degrees": 37}],
  "Polygons": [{
      "edges": [{}, {}, {}, {}],
      "angles": [{ "angle_degrees": 90 }, { "angle_degrees": 90 },
                 { "angle_degrees": 90 }, { "angle_degrees": 90 }]}],
      "edge_count": 4,
      "angle_count": 4,
      "angle_degrees": [90, 90, 90, 90],
      "largest_angle": 90,
      "sum_of_angles": 360,
      "is_triangle": false,
      "has_right_angle": true,
      "shape_type": "quadrilateral"
    }
  ]
}
```

Key Features Demonstrated

1. **Dynamic Property Calculation:**

- Edge and angle counts update automatically
- Shape type changes based on edge count
- Right angle detection
- Sum of angles calculation
2. **Triangle Properties:**
   - A polygon is classified as a triangle when it has exactly 3 edges
   - Right triangle detection when any angle equals 90 degrees
   - Sum of angles should be 180 degrees (or close to it with rounding)
3. **Quadrilateral Properties:**
   - Identified when a polygon has 4 edges
   - Sum of angles should be 360 degrees for a proper quadrilateral

Appendix B: Declarative Structure of Baseball Rules

Detailed aggregator formulas for events (OutEvent, RunEvent) and advanced sabermetrics (OPS, ERA, fielding percentage) in purely data-driven form.

Core Entities (Abbreviated)

Team

- **Fields**

  - `id` (PK)
  - `teamName`
  - `league_id` (lookup to a League)
- **Lookups**

  - `roster` → all Players on this team
- **Aggregations** *(examples)*

  - `wins` = COUNT(all Games where `winnerId = this.id`)
  - `losses` = COUNT(all Games where `loserId = this.id`)
  - `winPercentage` = `wins / (wins + losses)` if any games played
  - `rosterSize` = COUNT(roster)
  - `totalTeamRuns` = SUM(of all runs scored by this team)

Player

- **Fields**

  - `id` (PK), `fullName`, `battingHand` (L/R/S), `throwingHand` (L/R)
- **Lookups**

  - belongs to one `Team` (via `team_id`)
- **Aggregations** *(examples)*

  - `careerAtBats` = COUNT(AtBat where `batterId = this.id`)
  - `careerHits` = COUNT(AtBat with outcomes like SINGLE/DOUBLE/etc.)
  - `careerBattingAverage` = `careerHits / careerAtBats` (if atBats>0)
  - `ops` = `onBasePercentage + sluggingPercentage`

Game

- **Fields**

  - id (PK), homeTeamId, awayTeamId, status (e.g. IN_PROGRESS/FINAL)
- **Lookups**

  - innings → collection of Inning records for this game
- **Aggregations** *(examples)*

  - runsHome = SUM(of runs in half-innings where offensiveTeamId=homeTeamId)
  - runsAway = SUM(of runs in half-innings where offensiveTeamId=awayTeamId)
  - winnerId = if final & runs differ, whichever team is higher.
  - loserId = symmetric aggregator.

Inning / InningHalf

- **Inning**: references gameId, inningNumber, typically has a top/bottom half.

- **InningHalf**: references offensiveTeamId, defensiveTeamId; purely declarative "outs" and "runsScored" come from events:

  - outs = COUNT(OutEvent where inningHalfId=this.id)
  - runsScored = SUM(RunEvent where inningHalfId=this.id → runCount)
  - isComplete = true if outs≥3 **or** walk-off condition triggered

AtBat

- **Fields**
  - id, inningHalfId, batterId, pitcherId, result, rbi
- **Aggregations**
  - pitchCountInAtBat = COUNT(Pitch where atBatId = this.id)
  - batterHasStruckOut = (strikeCount >= 3)
  - wasWalk = (result='WALK')

Pitch

- **Fields**
  - id, atBatId, pitchResult (BALL, STRIKE, etc.), pitchVelocity
- **Aggregations** *(example)*
  - isStrike = true if pitchResult ∈ {CALLED_STRIKE, SWINGING_STRIKE}

OutEvent

- **Description**
  - A record that an out occurred. Ties to an inningHalfId and optionally an atBatId.
- **No "incrementOuts()"**
  - Simply create OutEvent → InningHalf.outs aggregator rises accordingly.

RunEvent

- **Description**

- ○ A record that one or more runs scored, referencing the half-inning (and possibly an at-bat).
  - **No "scoreRun()"**
    - ○ Summed by aggregator → `InningHalf.runsScored`.

Appendix C: A simple Cross Domain Synergy

C.1 Introduction

This appendix shows how **CMCC** unifies disparate domains—in this case, **Baseball** and **Economics**—under the same snapshot-consistent rulebook. By treating the two domains as sets of **Schema, Data, Lookups, Aggregations, and Lambda** fields, we demonstrate how an economic model can directly reference baseball facts (like a team's wins or attendance) to derive business or revenue metrics—all **without** writing imperative code.

C.2 Example: "TeamEconomics" Referencing the Baseball Domain

Entities from the Baseball Domain

- **Team**: Has fields (e.g., `id`, `teamName`) and aggregations like `winPercentage`, `currentWinStreak`, etc.
- **Game**: Tracks which team won or lost, attendance, etc.

New Entity: "TeamEconomics"
Let's define a minimal "TeamEconomics" entity that directly pulls aggregator values from the Baseball `Team` entity. This new entity can compute, for instance, ticket revenue as a function of the team's win percentage and attendance data.

json
CopyEdit
```
{
  "id": "CMCC_ToEMM_Economics_Baseball_Example",
  "meta-model": {
    "name": "Economics Extension to Baseball Domain",
    "description": "Illustrates how an economic aggregator (e.g., ticket revenue) can
depend on a baseball team's performance metrics.",
    "schema": {
      "entities": [
        {
          "name": "TeamEconomics",
          "description": "Captures revenue and morale for a baseball team in a given city,
referencing the baseball domain's 'Team' entity.",
          "fields": [
            {
              "name": "id",
              "type": "scalar",
              "datatype": "string",
              "primary_key": true,
              "description": "Unique identifier for this economics record."
            },
            {
              "name": "team_id",
```

```
        "type": "lookup",
        "target_entity": "Team",
        "foreign_key": true,
        "description": "Which baseball team this economics record corresponds to."
      },
      {
        "name": "cityName",
        "type": "scalar",
        "datatype": "string",
        "description": "The city or market where this team plays."
      }
    ],
    "lookups": [],
    "aggregations": [
      {
        "name": "averageAttendance",
        "type": "rollup",
        "description": "Pulls the baseball domain's aggregator for average
attendance across home games if that is tracked. Conceptual example.",
        "formula": "LOOKUP(TeamAttendance where teamId = this.team_id =>
averageHomeAttendance)"
      },
      {
        "name": "winPct",
        "type": "rollup",
        "description": "Directly references the baseball domain's aggregator
'winPercentage' on the Team entity.",
        "formula": "this.team_id.winPercentage"
      },
      {
        "name": "projectedTicketRevenue",
        "type": "rollup",
        "description": "Estimates ticket revenue from averageAttendance * some
function of the team's winPercentage.",
        "formula": "IF (winPct > 0.5) THEN (averageAttendance * 75) ELSE
(averageAttendance * 50)"
      },
      {
        "name": "cityMorale",
        "type": "rollup",
        "description": "Rough measure of local morale, which rises if the team's
currentWinStreak is high. Conceptual aggregator referencing a baseball aggregator.",
        "formula": "IF (this.team_id.currentWinStreak >= 5) THEN 1.2 ELSE 1.0"
      }
    ],
    "lambdas": [
      {
```

```
            "name": "simulatePriceChange",
            "parameters": ["ticketPriceFactor"],
            "description": "A purely declarative constraint that sets an updated formula
for 'projectedTicketRevenue' if the city decides to raise/lower ticket prices.",
            "formula": "this.projectedTicketRevenue = (this.projectedTicketRevenue *
ticketPriceFactor)"
          }
        ],
        "constraints": []
      }
    ],
    "data": {
      "TeamEconomics": [
        {
          "id": "ECON_001",
          "team_id": "TEAM_NYY",
          "cityName": "New York"
        },
        {
          "id": "ECON_002",
          "team_id": "TEAM_BOS",
          "cityName": "Boston"
        }
      ]
    }
  }
}
}
```

C.3 Explanation of the Key Fields and Formulas

1. **team_id**
   A **lookup** that directly references the **Baseball** domain's Team entity. The aggregator formulas in TeamEconomics can thus pull any baseball field or aggregator exposed by Team.

2. **averageAttendance**
   Illustrates a hypothetical aggregator that looks up a "TeamAttendance" measure (or any other baseball domain aggregator). It might sum or average attendance from all of the team's home games.

3. **winPct**
   Directly references the baseball domain's aggregator Team.winPercentage. This is a single expression—no imperative "fetch or recalc" step required.

4. **projectedTicketRevenue**
   Combines the above (averageAttendance and winPct) into a single formula. If the team's winPct is above 0.5, we assume an increased ticket revenue (75 currency units per attendee vs. 50 otherwise).

5. **cityMorale**
   Similarly ties into `currentWinStreak` on the baseball `Team`, increasing city morale if the streak is high. No "callFunctionToUpdateMorale()`" ever runs; the aggregator auto-updates whenever currentWinStreak` changes.

6. **Lambda Example** – `simulatePriceChange`
   While not strictly necessary, it demonstrates how a purely declarative formula can express "update constraints" such as changing ticket pricing. Internally, it's still a statement about "what is true if price factor changes," rather than an imperative directive.

C.4 Snapshot Consistency Across Domains

- **No Special "Integration Step"**
  In a typical procedural system, you might need a separate script or API call to sync baseball performance data with an economics module. Under CMCC, once `Team.winPercentage` changes, everything referencing it (like `projectedTicketRevenue`) automatically sees the updated value in the next committed snapshot.

- **Scalability**
  This approach scales to any number of domains, as each domain's schema and aggregations can read or reference aggregator outputs from the others. For instance, you could add "MerchandiseSales" or "SponsorDeals" entities that also incorporate `winPercentage` or `averageAttendance` with no new custom function calls required.

- **Clarity and Maintainability**
  Economic constraints and formulas now live in the same declarative environment as baseball's runs, outs, or attendance. If you want to adjust how revenue is computed (e.g., weigh attendance more heavily), you simply revise the aggregator formula in `TeamEconomics`.

C.5 Takeaway

This short example demonstrates the **cross-domain synergy** that emerges naturally from CMCC. A single snapshot-consistent system can carry **baseball** logic (teams, runs, aggregator-driven outcomes) while simultaneously expressing **economic** logic (ticket revenue, city morale, pricing) in the same rulebook—no manual bridging code or "glue scripts" needed. As the team's performance changes, so do the economic metrics, purely by virtue of shared aggregator fields and lookups.