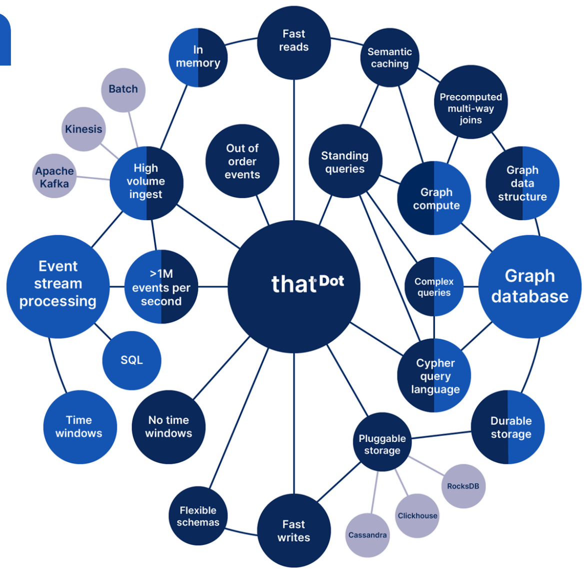
Streaming Graph Data Processing

Designed to find complex patterns within high volume data streams composed of heterogeneous feeds without resort to time windows.



Origins and Challenges

Stream processing and event-driven microservices are complicated! They're complicated because they combine the hardest problems from the database domain with the hardest problems from the distributed systems domain.

At their core, both domains bring a long list of challenges that are due to the complex interplay of fundamental mathematical or physical constraints that will inevitably surface in any system that stores data and has more than one processor.

Researchers and developers spend entire careers developing novel ways to overcome the constraints and tradeoffs of a single aspect of these systems. Issues like consensus, concurrency, transactional logic, clustering behavior, fault tolerance, scalability, balancing read and write performance tradeoffs, and temporal ordering are all subjects of research and innovation.

However, when the system in question is primarily concerned with processing events as quickly as possible, one dimension in particular takes on outsized importance: time.

Quine is an open source streaming graph software project sponsored by thatDot.
Learn more at thatdot.com.

Streaming Graph for Real-Time Applications

Quine is the open-source streaming graph and computation platform developed by the engineers at thatDot. It bridges the worlds of distributed event stream processing engines and graph databases.

Quine is designed to find complex patterns within high volume data streams composed of heterogeneous feeds without resort to time windows. It eliminates the headaches involved with building and operating event-driven microservices that enable real-time applications.

Core Design Choices and Their Implications

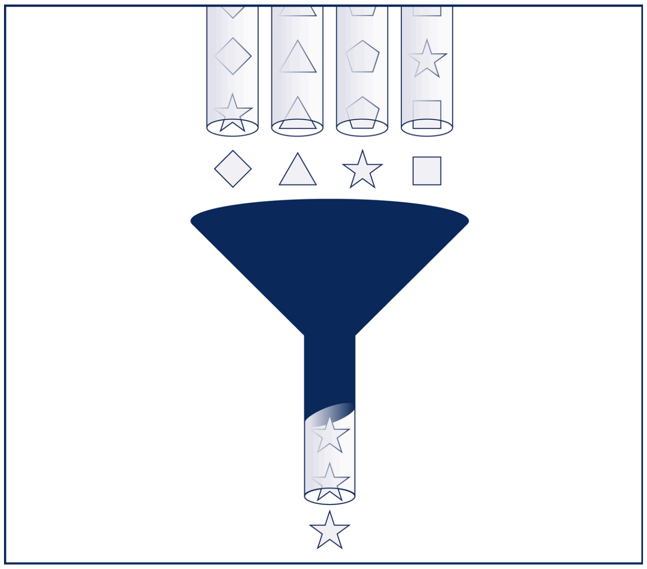
Three design choices define Quine, setting it apart from all event stream processing systems: a graph-structured data model, an asynchronous actor-based graph computational model, and standing queries, which are Quine's solution to the challenges time presents in distributed systems, and are similar to continuous queries in other event stream processors.

1. Graph-Structured Data Model
2. Actor-Based Graph Computational Model
3. Standing Queries

Time and Distributed Systems

Processing vast amounts of event data, especially when the system is composed of many microservices that rely on a strict order of operations, presents particular challenges. How does such a system handle out-of-order data? What if data arrives hours, days, or months after it was generated? And how will such a system know when to execute a query? When will the system be guaranteed to have all the data and in proper order?

Consider for instance the previously mentioned problem of when to query data. Systems today must continuously query, or poll. Polling consumes system resources and increases query latency, both of which impact not just the process or service in operation at the moment, but have the knock on effect of delaying when the next service can guarantee that it has the necessary data.



A New Approach

What if we could eliminate many of the drawbacks of event processing and database systems and build a system from the ground up which confronts each of these fundamental challenges from a holistic perspective and with the goals of modern applications in mind? What if we could build a system to deliver high-throughput, low-latency reads and writes over unbounded data? One that is optimized to handle the constraints of distributed systems and databases under high concurrency workloads?

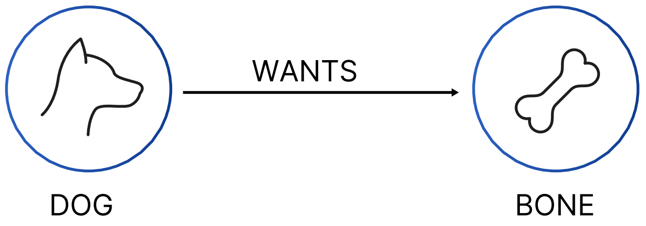
After seven years of research and development, and with major funding from DARPA, this is exactly what the team at thatDot has done. We call this system Quine. This open source system is at the heart of all thatDot technology.

1 Graph is the Universal Data Structure

Quine uses a property graph model to store and query real-time data. In this regard, it functions similarly to graph databases. It even uses the most common graph query language, Cypher, to work with the data. In a graph model, data is represented as nodes connected to each other by edges. Nodes hold key-value pairs of “properties.” The edges have a direction and a label, and connect exactly two nodes.

Graph data structures represent data and its relationships in a way strikingly similar to how humans often think and talk about data. The node-edge-node pattern in a graph corresponds directly to the subject-predicate-object pattern common to languages like English. This makes graphs both powerful and easy to understand. When visualized, a graph becomes endlessly intriguing.

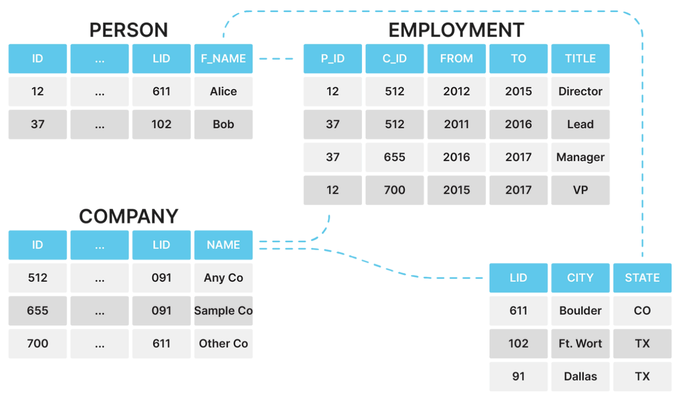
Quine’s property graph structure puts relationships at the same level as the data values themselves by encoding these relationships as edges. To discover relationships, one need only traverse a node’s edges. Traversing the edge of a node to its neighbor is analogous to computing a join across tables in a relational data model.



However, unlike relational databases, these relationships are essentially pre-computed joins. They make it easy and extremely efficient to use the relationships in data—which is how Quine is able to find complex patterns across both high-volume heterogeneous data streams and large historical data sets in real time.

Quine and thatDot Streaming Graph

In general, Quine OSS is for single node use cases which do not require commercial support. thatDot Streaming Graph, has Quine at it’s heart, but is useful for larger use cases that require a distributed cluster for production execution. Newer versions of thatDot Streaming Graph, also have expanded capacity for enterprise use cases with support for separating different datasets into Namespaces.



PERSON

ID	...	LID	F_NAME
12	...	611	Alice
37	...	102	Bob

EMPLOYMENT

P_ID	C_ID	FROM	TO	TITLE
12	512	2012	2015	Director
37	512	2011	2016	Lead
37	655	2016	2017	Manager
12	700	2015	2017	VP

COMPANY

ID	...	LID	NAME
512	...	091	Any Co
655	...	091	Sample Co
700	...	611	Other Co

LID	CITY	STATE
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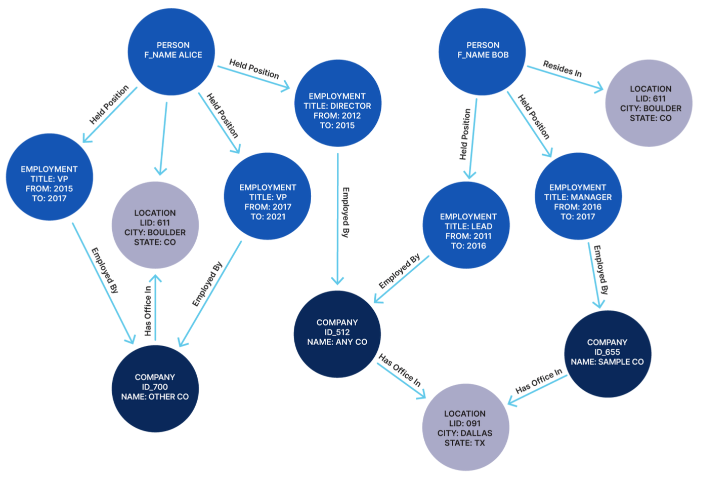
102	Ft. Wort	TX
91	Dallas	TX


PERSON F_NAME ALICE
Held Position
EMPLOYMENT TITLE: DIRECTOR FROM: 2012 TO: 2015
Held Position
EMPLOYMENT TITLE: VP FROM: 2015 TO: 2017
LOCATION LID: 611 CITY: BOULDER STATE: CO
Held Position
EMPLOYMENT TITLE: VP FROM: 2017 TO: 2021
Employed By
Has Office In
Employed By
COMPANY ID_700 NAME: OTHER CO
Employed By
COMPANY ID_512 NAME: ANY CO
PERSON F_NAME BOB
Resides In
LOCATION LID: 611 CITY: BOULDER STATE: CO
Held Position
EMPLOYMENT TITLE: LEAD FROM: 2011 TO: 2016
Held Position
EMPLOYMENT TITLE: MANAGER FROM: 2016 TO: 2017
Employed By
Employed By
COMPANY ID_655 NAME: SAMPLE CO
Has Office In
Has Office In
LOCATION LID: 091 CITY: DALLAS STATE: TX

2 A Graph Model for Asynchronous Computation: the Actor Model

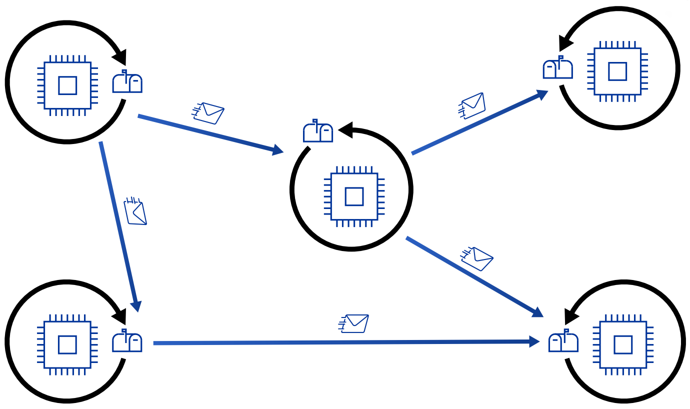
In Quine, the graph data model is paired with a graph computational model. Computation is implemented as a native graph interpreter which occurs directly on the data. Ingested data, queries, or other instructions are inserted into the graph and propagate through the network of nodes and edges to compute the appropriate answer or trigger an action. The result is a fast and efficient process for highly parallel and fully asynchronous computation that executes inside the graph.

Computation in Quine is built on the Actor Model originally using Akka, but later updated to its open source successor, Pekko. First described by Carl Hewitt* in 1973, an actor is a lightweight, single-threaded process that encapsulates state and communicates with the outside world only through message passing. An actor receives messages in its mailbox and performs the corresponding small-scale computation.

Actors are scheduled for computation concurrently with other actors. This makes the overall system computation highly parallel. Under heavy load, the scheduler utilizes all available CPU cores automatically, scheduling multiple separate actors to process their messages concurrently. Actor scheduling is done on a highly-efficient "work-stealing" fork-join thread pool, running efficiently on a small machine, or taking advantage of massive compute resources available on large machines.

This also means that Streaming Graph distributed use cases make efficient use of each machine in a cluster, keeping cluster sizes reasonable, even for jobs with intense computational demands. The net result of these is a fast, efficient, reactive system that provides very high throughput for complex event processing.

* https://arxiv.org/vc/arxiv/papers/1008/1008.1459v8.pdf



MESSAGE HANDLING

- Provides universal, event-driven, incremental computation
- Implements complex protocols
- Mixed in to nodes
- Easily extended
- Built on the battle-tested Pekko OSS

3 Standing Queries Change Everything

Standing queries are the central innovation at the heart of Quine. Built on the pillars of the graph data and computational models, standing queries in Quine eliminate the time-based challenges otherwise inherent to distributed systems. But the implications of what they mean for building complex systems with Quine reach far beyond that.

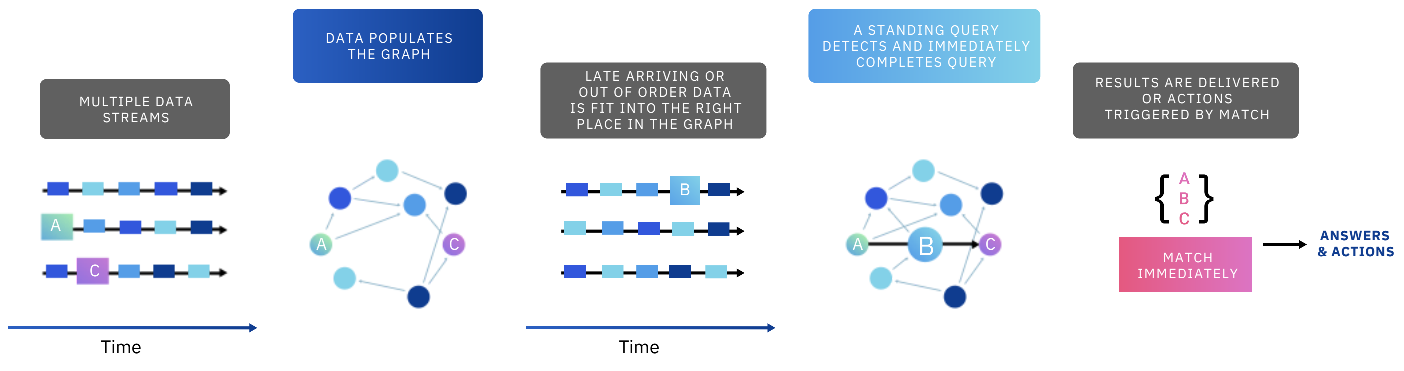
Standing queries live inside the graph and automatically propagate their incremental results computed from both historical data and incoming streaming data. Once matches are found, standing queries trigger actions using those results (e.g. report results, execute code, transform other data in the graph, publish data to another source).

This eliminates the need for constant polling to discover new changes in the data. Because standing queries persist in the graph, incrementally updating partial results as new data arrives, you are not just querying the past and present state, you are querying the future for any matches from data yet to arrive.

Out of Order and Late Arriving Data With No Time Windows

Quine's standing query capability allows it to easily handle out-of-order data and late-arriving data. A standing query is issued, ready to complete the sought-after pattern with no consideration of data arrival order, even if delayed by hours or months. Because Quine lets the user focus on the structure of the data instead of the order of events—even if data arrives entirely backwards—Quine will provide the correct answers immediately when all the relevant data has arrived.

Instead of needing to continuously poll to determine if data has arrived, as you must with other event processing systems, Quine's state is continuously updated and each match triggers the appropriate action automatically. Because data is stored on disk, retrieved and managed automatically, new data can easily be combined transparently with very old data. Because results stream out immediately when a match is found, standing queries eliminate the need to keep checking whether the data is complete—eliminating all the operational complexity and wasted resource overhead that entails. Instead you can focus attention on the business problems that led you to implement an event-driven architecture in the first place.


MULTIPLE DATA STREAMS
A
C
Time
DATA POPULATES THE GRAPH
A
C
LATE ARRIVING OR OUT OF ORDER DATA IS FIT INTO THE RIGHT PLACE IN THE GRAPH
B
Time
A STANDING QUERY DETECTS AND IMMEDIATELY COMPLETES QUERY
A
B
C
RESULTS ARE DELIVERED OR ACTIONS TRIGGERED BY MATCH
{ A B C }
MATCH IMMEDIATELY
ANSWERS & ACTIONS

Performance and Flexibility

Quine’s architecture gives rise to some novel and quite powerful capabilities that directly address the tradeoffs and limitations of existing distributed stream processing systems.

High Read and Write Performance

Quine’s graph-based data and computational model also make it possible to achieve both high read and high write performance.

High read performance is achieved through an approach we call semantic caching. The graph data structure, specifically the edges between nodes, provides what are effectively pre-computed joins for the entire data set, but they are computed incrementally at the moment when it is most efficient. With the connections in the data easily accessible, they become the ideal clue to what other data is worth keeping warm in the cache.

Semantic caching is another key to Quine’s high-throughput and low-latency computation. With related data kept in memory, the result is a remarkably high cache hit rate and great performance.

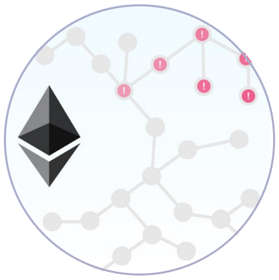
Quine’s actor-based compute model is also key to achieving high write throughput. Since each node is an actor and has the ability to do arbitrary computation, Quine can efficiently test whether updates or writes actually need to be stored on disk. If they do, Quine writes only the minimum possible delta. This operation is then combined with a write-optimized data store like RocksDB or Cassandra to deliver fast and efficient write operations. Clickhouse is also among the options in the more recent versions.

Quine’s high-throughput and low-latency computation is made possible by the unified graph representation of both data and computation.

Balance: Schema-less Flexibility with Schema-full Data Structure

Quine’s unified graph provides the ideal sweet spot between flexibility and structure in the schema. You do not always have to know the shape of all data before the first write, and yet can still query and compute on the data efficiently and reliably.

https://quine.io/recipes.html



Real-Time Tag Propogation Across a Block Chain

The Ethereum blockchain is ingested live from the Web, transactions are modeled in the Quine streaming graph and a Quine Standing Query propagates a “dirty money” tag in real-time across the graph to trace money laundering.

CDN Cache Efficiency By Segment

Ingest CDN logs and calculate cache hit rate in real time by segments: Country, State, PoP, ASN to generate alerts or dashboards.

Kubernetes Event Observability

Ingest Kube events and calculate state by component, pod, & service to generate alerts and trace root causes.

About thatDot

- In 2014, Ryan Wright, founder and CEO of thatDot, after he decided that he’d rebuilt the same event processing micro service platform one too many times, invented Quine.
- In 2015, Wright lead a team of researchers and developers on the DARPA Transparent Computing program to create new capabilities for finding and stopping Advanced Persistent Threats (APTs). Using a graph data structure made joining and processing categorical data from multiple sources world’s easier, faster, and more efficient.
- In 2022, thatDot announced an investment from Crowdstrike’s Falcon Fund and was founded as a commercial company. thatDot is a Portland, Oregon-based streaming event processing company. thatDot technology analyzes infinite datasets in real-time. Built on our native streaming graph technology, our commercial applications, Streaming Graph and Novelty, are ideal for cybersecurity, anomaly detection, fraud prevention, and a variety of other applications.

Try thatDot for yourself

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