GraphAlg: Efficient Execution of User-Provided Graph Algorithms in a Graph Database

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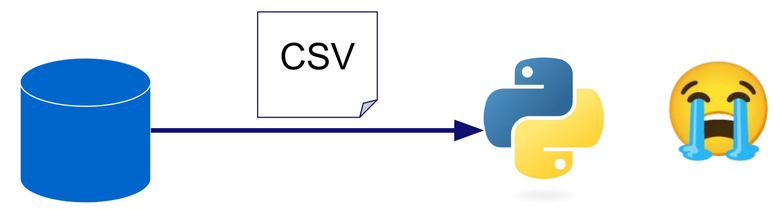
GraphAlg is a **domain-specific language** for high-performance **graph analytics**. Designed to be **embedded in the AvantGraph database**, it is more **expressive** than traditional query languages while remaining highly **amenable to optimization**.

Problem: Low Programmability

If your algorithm cannot be expressed in the query language (e.g., Cypher), the graph database quickly becomes a **dumb storage layer. Exporting large volumes of data is expensive** in terms of compute and storage, and in the process all **data statistics are lost**.




```
CALL export.csv.all("database.csv")
```

Low programmability forces users to export data and use external tools.

Solution: GraphAlg

A language for writing graph algorithms, designed to be integrated into graph databases.

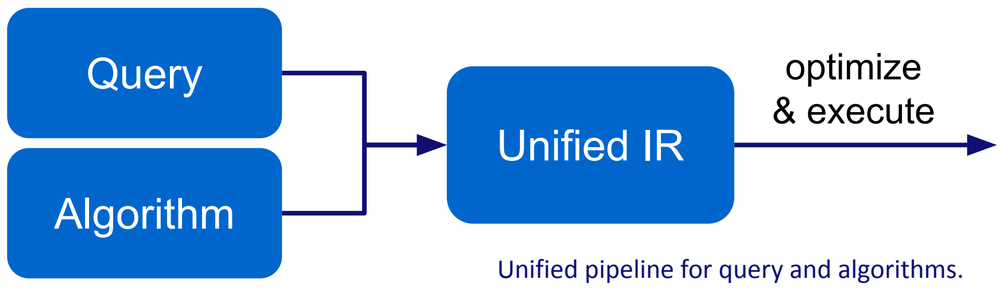
- **Fully integrated with AvantGraph**. Embed algorithms into Cypher queries.
- **Eliminates data wrangling** by operating inside of the database.
- **Purpose-built for graph algorithms**. Based on linear algebra, it can concisely express a wide variety of algorithms.
- **Highly optimizable**. A small, high-level core language with formal semantics.

```
func SSSP(graph: Matrix<s, s, trop_real>,
          source: Vector<s, bool>)
          -> Vector<s, trop_real> {
  v = cast<trop_real>(source);
  for i in graph.nrows {
    v += v * graph;
  }
  return v;
}
```

Single-Source Shortest Paths in GraphAlg.

Cross-Optimization

AvantGraph has **full visibility into GraphAlg programs**. The query and any embedded algorithms are transformed into a unified IR that is **holistically optimized and executed**, enabling optimizations that cross the border between query and algorithm.



Unified pipeline for query and algorithms.

Core Language

GraphAlg can be reduced to a small *core* language with well-defined **operational semantics**. The core language is **equivalent to MATLANG**[1] with a limited form of iteration. Our **novel loop construct** is expressive enough to support efficient implementations of commonly used algorithms, yet limited enough that it remains amenable to analysis and optimization.

GraphAlg compiler pipeline.

Approach	Key Problems	Used by
Built-in Algorithms Library	- Fixed set of Algorithms	neo4j
Pregel API	- Performance issues - Not analysable	ArangoDB
User-defined operators	- Unsafe - Not analysable	UMBRA
Recursive CTE	- Difficult to write - Performance issues	
Procedural SQL	- Overhead - Limited analysis	ORACLE
Algorithm DSL	- Proprietary - No integration with queries	Oracle Labs PGX

Different approaches to graph analytics in databases.

[1] Robert Brijder, Floris Geerts, Jan Van Den Bussche, and Timmy Weerwag. 2019. On the Expressive Power of Query Languages for Matrices. ACM Trans. Database Syst.

Database Group

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