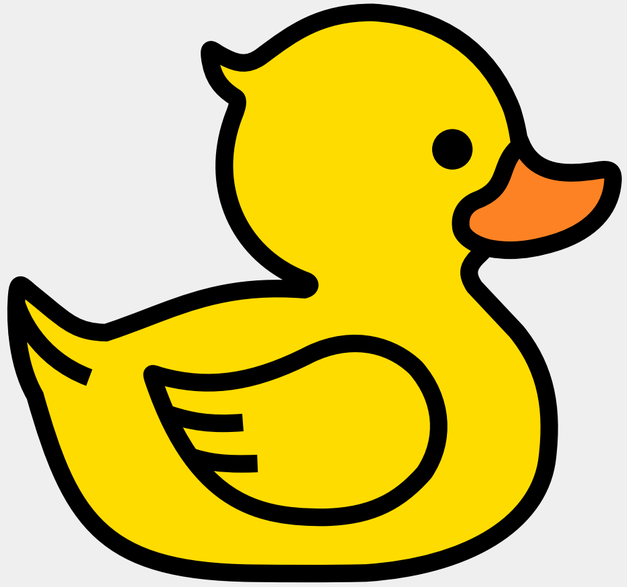
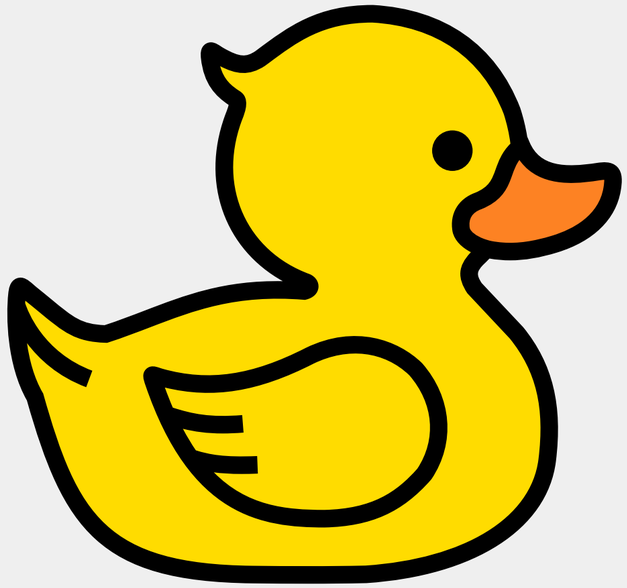
Implementing & Flattening Nested LATERAL joins in DuckDB



$$D \bowtie T$$

Sam Arch, Mayank Baranwal, Arham Chopra

FLATERAL



$$D \bowtie T$$

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Outline

1) LATERAL joins and why we need them for UDFs

2) Project Goals

3) Live Demo

4) Approach

5) War Stories

6) Future Work & Takeaways

User-Defined Functions (UDFs)

```
CREATE OR REPLACE FUNCTION fib(x INT)
RETURNS INT AS
$$
DECLARE
  fib1 INT := 0;
  fib2 INT := 1;
  fib3 INT := 1;
BEGIN

  FOR i IN 1..x LOOP
    fib3 = fib1 + fib2;
    fib1 = fib2;
    fib2 = fib3;
  END LOOP;

  RETURN fib1;

END;
$$ LANGUAGE plpgsql;

SELECT fib(42);
```

Reusability ✓

Modularity ✓

Readability ✓

UDFs are Slow

No UDF

Fast

UDF

Slow

Up to 10,000x slower

UDF Inlining to the Rescue!

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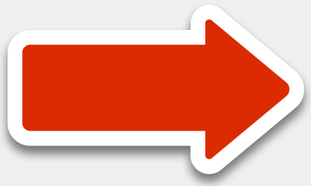

```
WITH RECURSIVE run("rec?", "res", "x", "fib1", "fib2", "i") AS
    (
        (SELECT True, NULL :: int4, "x", "fib1_1", "fib2_1", "i_1"
         FROM LATERAL (SELECT 0 AS "fib1_1") AS "let0"("fib1_1"),
              LATERAL (SELECT 1 AS "fib2_1") AS "let1"("fib2_1"),
              LATERAL (SELECT 1 AS "i_1") AS "let2"("i_1"))
          UNION ALL
        (SELECT "result".*
         FROM run AS "run"("rec?", "res", "x", "fib1", "fib2", "i"),
              LATERAL
              (SELECT "ifresult6".*
               FROM LATERAL (SELECT "x" AS "q2_2") AS "let4"("q2_2"),
                    LATERAL (SELECT "i" <= "q2_2" AS "pred3_2") AS "let5"("pred3_2"),
                    LATERAL
                    ((SELECT True, NULL :: int4, "x", "fib1_4", "fib2_4", "i_4"
                      FROM LATERAL
                           (SELECT "fib1" + "fib2" AS "fib3_4") AS "let7"("fib3_4"),
                           LATERAL (SELECT "fib2" AS "fib1_4") AS "let8"("fib1_4"),
                           LATERAL (SELECT "fib3_4" AS "fib2_4") AS "let9"("fib2_4"),
                           LATERAL (SELECT "i" + 1 AS "i_4") AS "let10"("i_4")
                      WHERE NOT "pred3_2" IS DISTINCT FROM True)
                       UNION ALL
                     (SELECT False,
                             "fib1" AS "result",
                             "run"."x",
                             "run"."fib1",
                             "run"."fib2",
                             "run"."i"
                      WHERE "pred3_2" IS DISTINCT FROM True)
                    ) AS "ifresult6"
              ) AS "result"
         WHERE "run"."rec?")
    )
    SELECT "run"."res" AS "res"
    FROM run AS "run"
    WHERE NOT "run"."rec?"
```

LATERAL Joins

```
WITH RECURSIVE run("rec?", "res", "x", "fib1", "fib2", "i") AS
    (
        (SELECT True, NULL :: int4, "x", "fib1_1", "fib2_1", "i_1"
         FROM LATERAL (SELECT 0 AS "fib1_1") AS "let0"("fib1_1"),
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              ) AS "result"
         WHERE "run"."rec?")
    )
    SELECT "run"."res" AS "res"
    FROM run AS "run"
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```
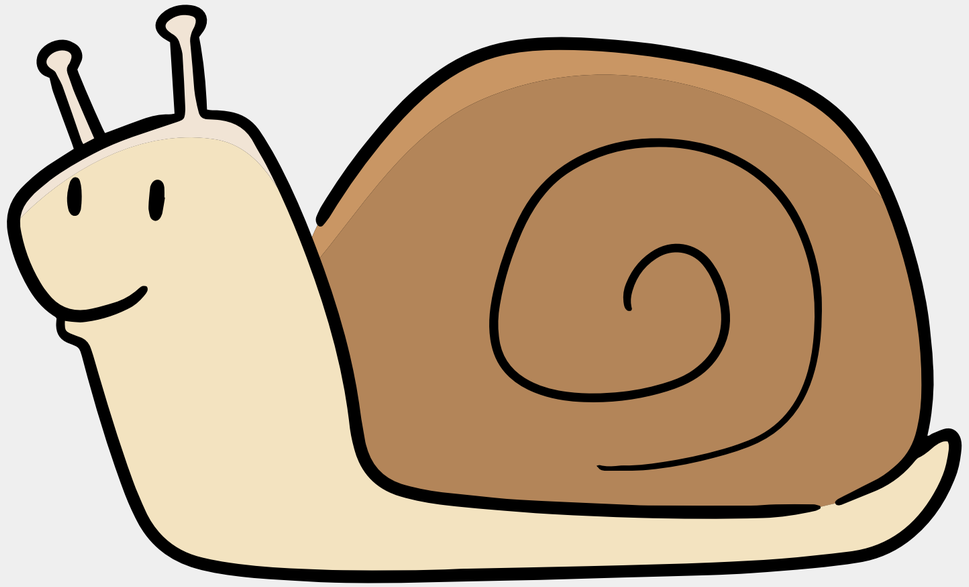
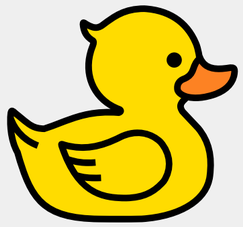

For **each LATERAL**:

For **each row** in LHS:

Evaluate the RHS



Why DuckDB?



```
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         FROM LATERAL (SELECT 0 AS "fib1_1") AS "let0"("fib1_1"),
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                             "run"."i"
                      WHERE "pred3_2" IS DISTINCT FROM True)
                    ) AS "ifresult6"
              ) AS "result"
         WHERE "run"."rec?")
    )
    SELECT "run"."res" AS "res"
    FROM run AS "run"
    WHERE NOT "run"."rec?"
```

LATERAL JOIN → **HASH JOIN**

Flattening

You need a good query optimizer!

Project Goals

Implement & flatten nested LATERAL joins

75% - Fixed depth LATERALs (i.e. depth = 2)

100% - Arbitrary depth LATERALs

125% - Full UDF support (Recursive CTEs + LATERALs)

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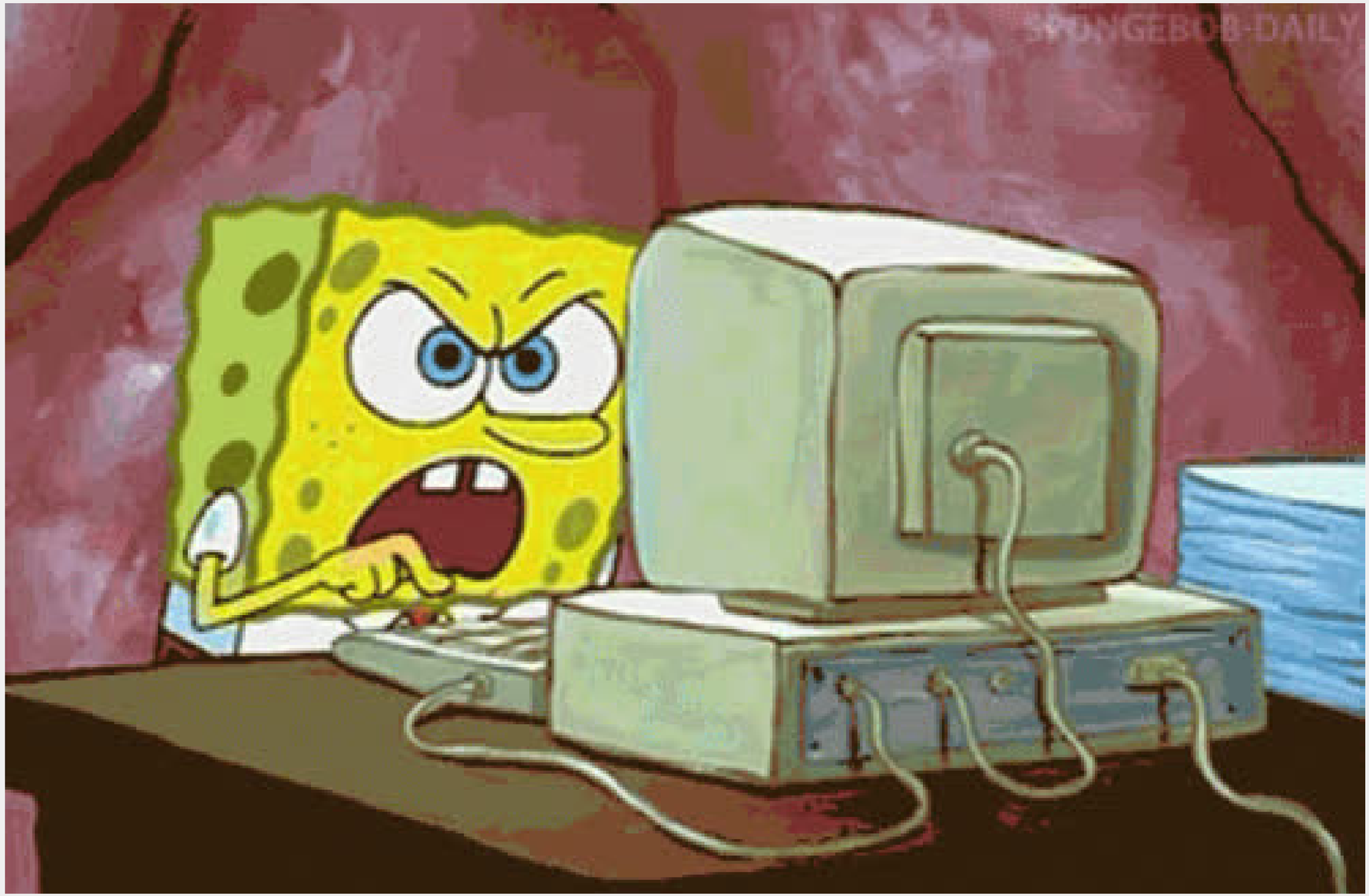
125%* - Full UDF support (Recursive CTEs + LATERALs)

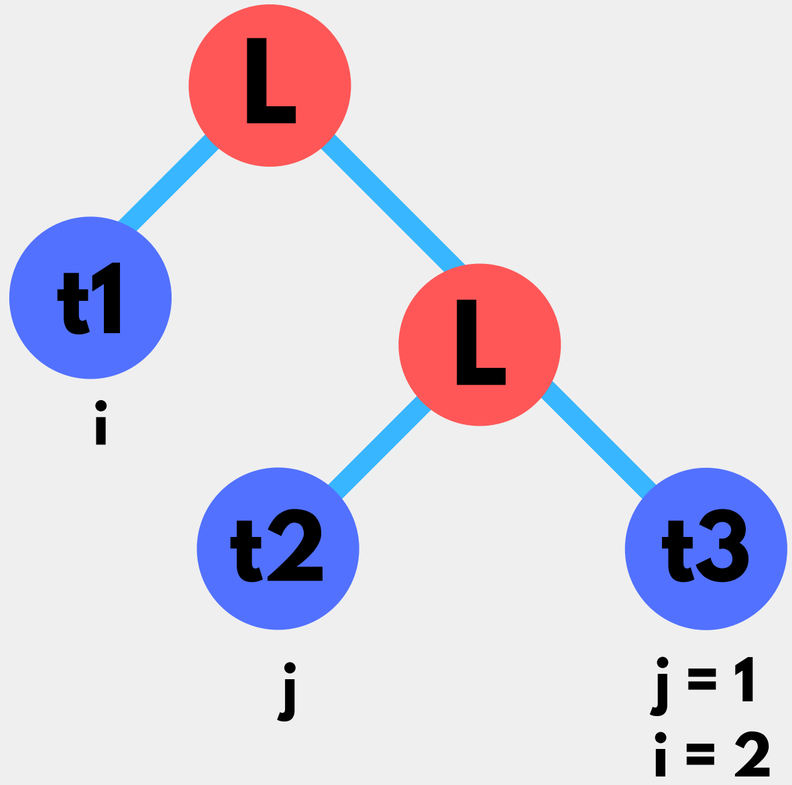
* T&C Apply (explained later)

Live Demo



Approach

```
SELECT *
  FROM
         (SELECT 1) t1(i),
LATERAL (SELECT *
           FROM
                (SELECT 2) t2(j),
         LATERAL (SELECT i + j) t3(k));
```

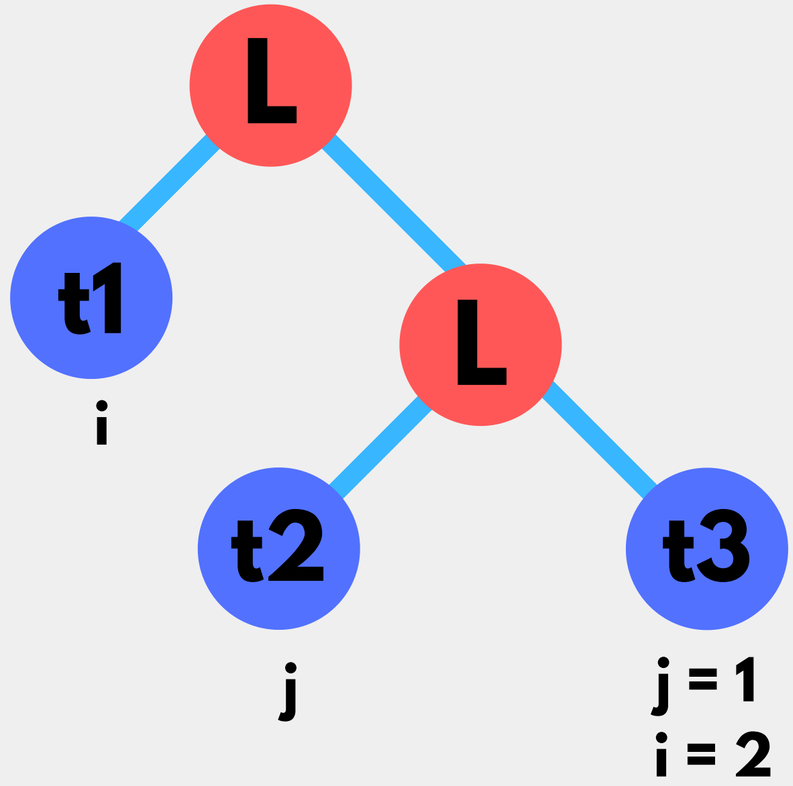


Original Codebase

- Binder: Not able to handle correlations in nested laterals
- Planner: Plans nested laterals in an incorrect way, causing failures
- Assumptions in the code on only one level of laterals

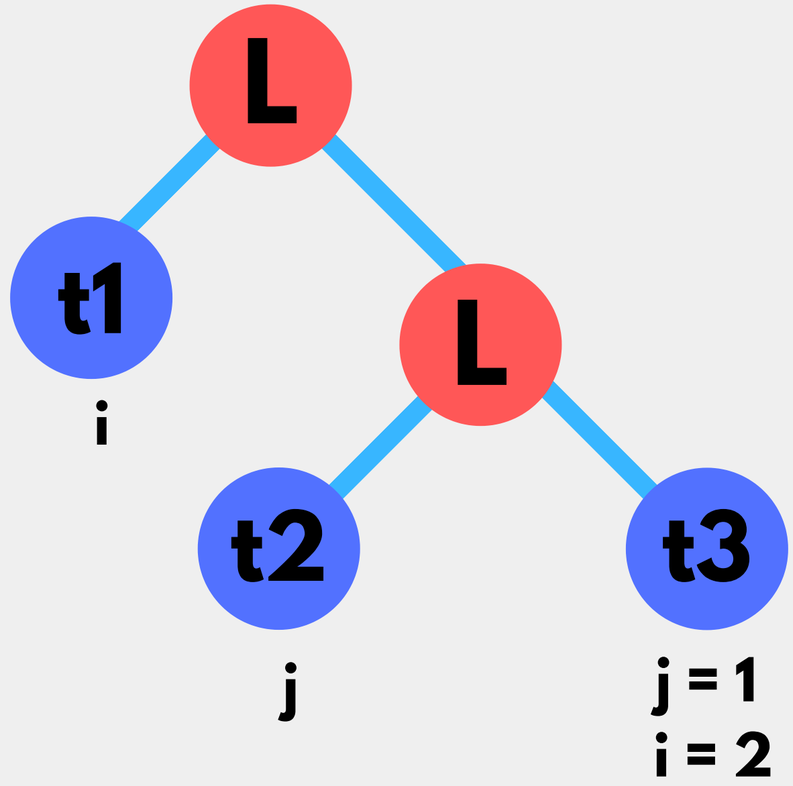
Approach

- **Binder:**
  - Bind laterals recursively
  - Track correlations correctly
  - Maintain correct depth information



Approach

- **Planner**:
  - Change planning order: top-down
  - Detect correlations correctly
  - Push-down correlations through all the relevant nodes
  - Rewrite column bindings



Validation

Tests	Status
Our Stress Tests (verified against UMBRA)	✓
PostgreSQL tests for LATERALs and Subqueries	✓
DuckDB Tests for LATERALs and Subqueries	✓
DuckDB Regression Tests (for PR)	✓
DuckDB CI Tests (for PR)	✓
SQLite Tests for LATERALs (the holy grail)	Don't Exist ¯_(ツ)_/¯

Now for the War Stories

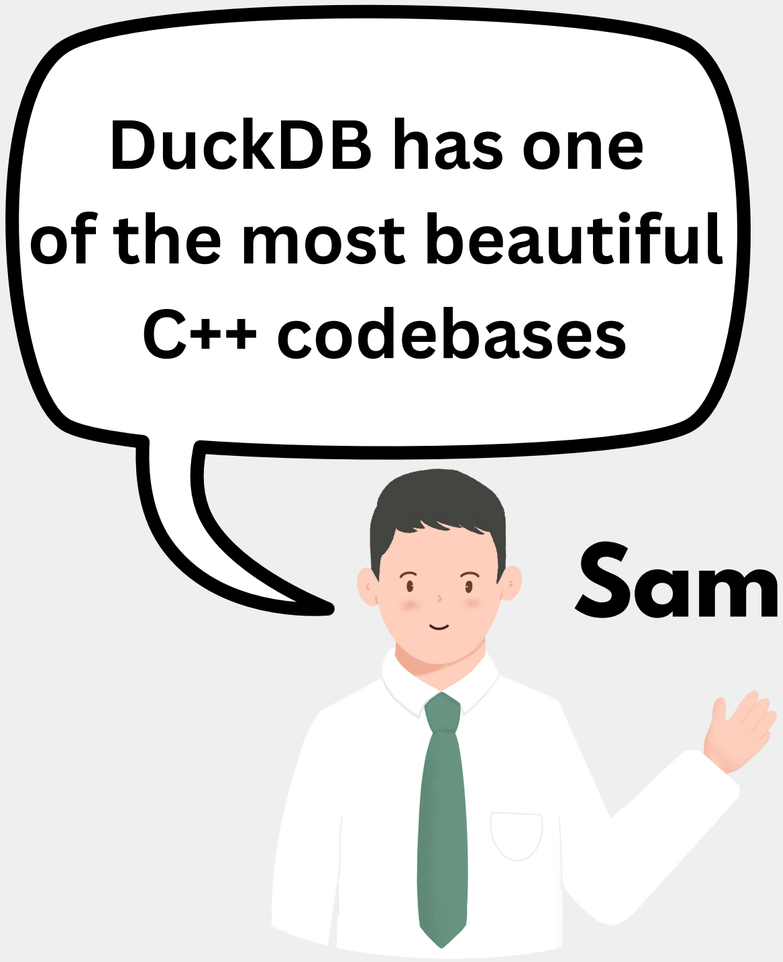
A tale of misery, suffering and joy

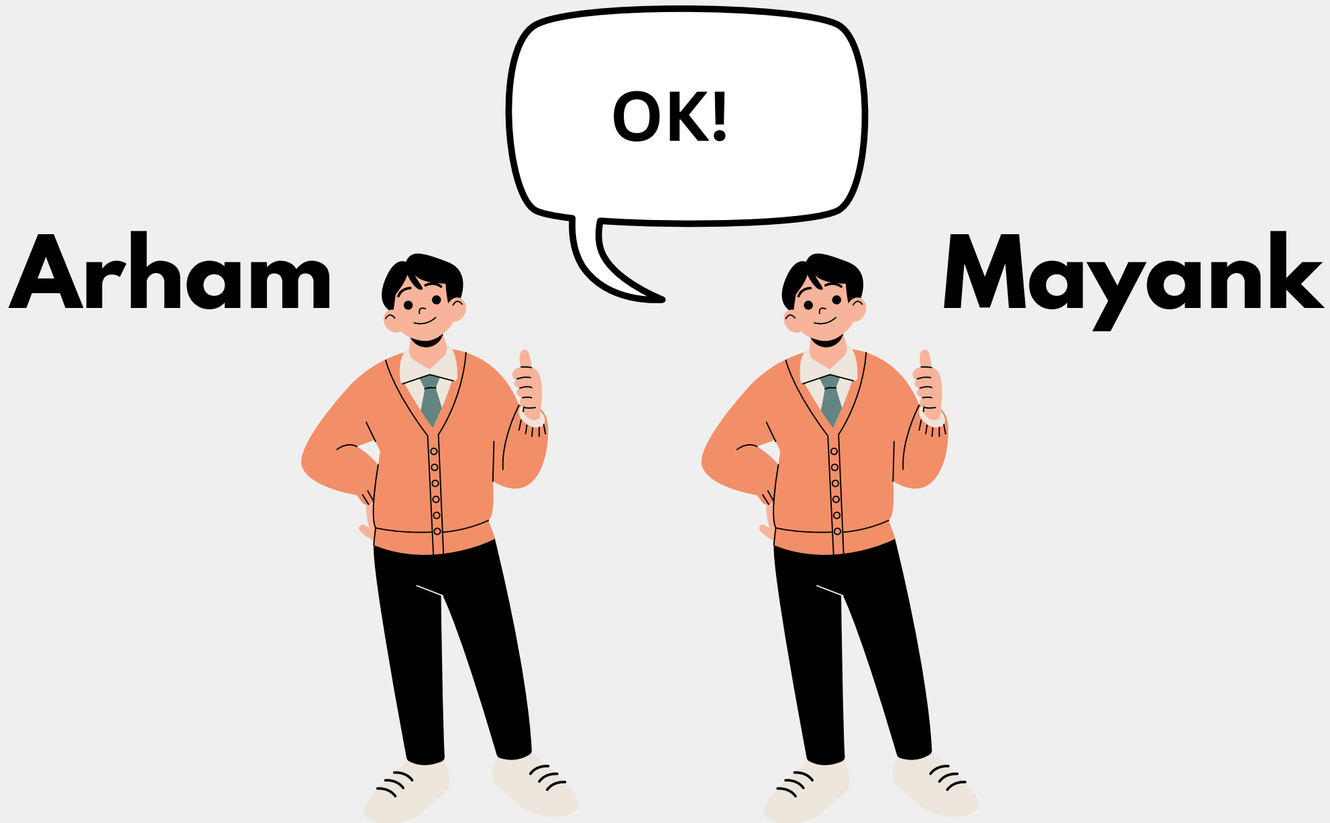
Let's do flattening they said
It will be easy they said

...

- Mark Raasveldt
(maybe not really)

The Prologue





Reading the Codebase

Especially with close to NO COMMENTS

After weeks of procrastinating and struggling with the code

And after multiple failed attempts

Mark when he tells us "Godspeed"

Debugging Binder Code

Debugging Binder Code

And Logical Planner Code

Debugging Binder Code

And Logical Planner Code

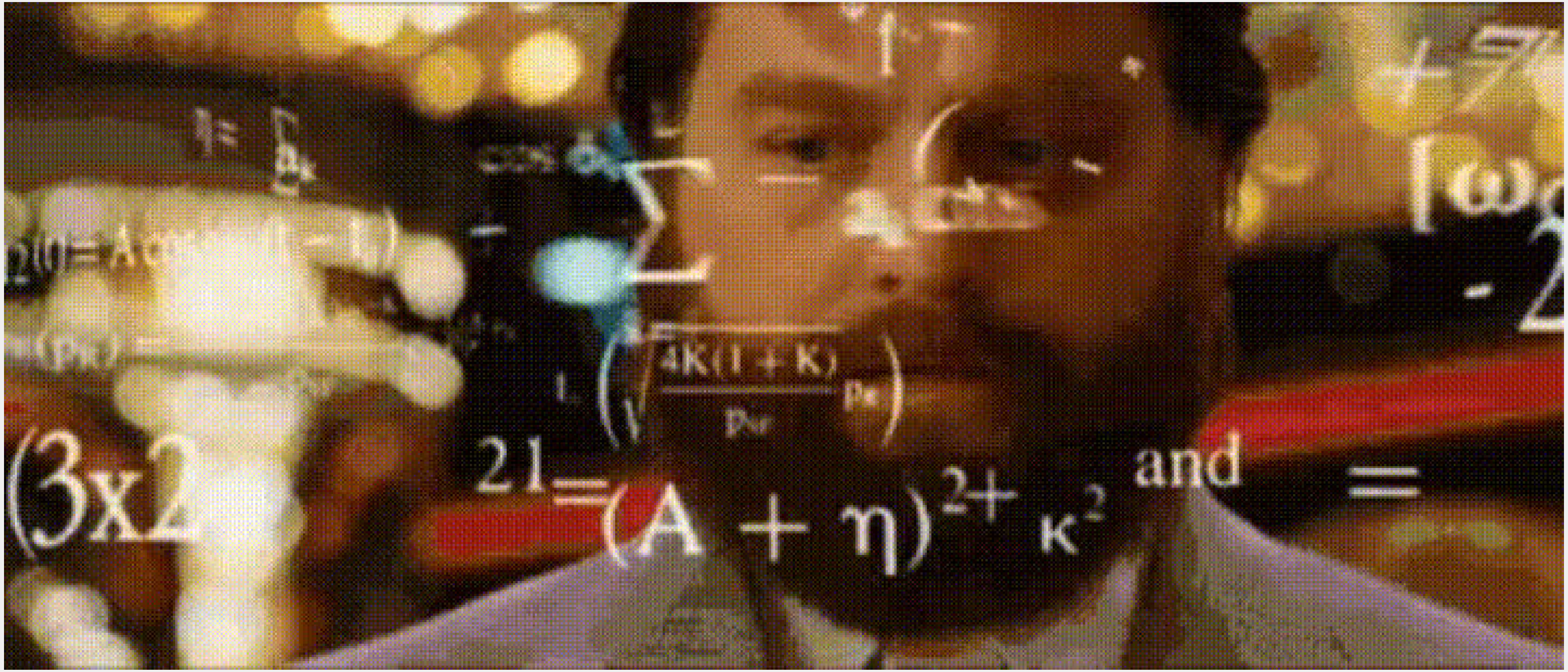
And Physical Planner Code

When 3 million tests pass

But then 2 tests fail

But then 2 tests fail

Revamping the whole logic



Then all tests pass

Future Work

- Put in a Pull Request to DuckDB (refactoring required)
- Benchmark the UDFs in the ProcBench on DuckDB
- Compare DuckDB and Umbra on the ProcBench
- Convince the world to use UDFs 

... So that Sam can get his PhD :)

Takeaways

- The Binder/Rewriter is extremely tricky
  - But when it makes sense, it just works
- Extensive Testing & Rapid Prototyping go very far
- Drawing diagrams & (Constructive?) Arguing = Progress

- Real database development is HARD
- This is why DB companies pay us the big bucks

Questions?