Virtual Mutation Analysis of Relational Database Schemas

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Relational Databases – Why Should We (Still) Care?

A vital component of many software systems

Despite the wave of interest in “NoSQL” technologies, Relational Databases are still popular (and faster)

For developers: schemas provide self-documentation

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Relational Databases are still important, popular and relevant

A Relational Database Schema

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CREATE TABLE Station (
  ID INTEGER PRIMARY KEY,
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  STATE CHAR(2),
  LAT_N INTEGER NOT NULL
    CHECK (LAT_N BETWEEN 0 and 90),
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);
CREATE TABLE Stats (
  ID INTEGER REFERENCES STATION(ID),
  MONTH INTEGER NOT NULL
    CHECK (MONTH BETWEEN 1 AND 12),
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    CHECK (TEMP_F BETWEEN 80 AND 150),
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Column and data type

Integrity Constraints

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Testing the Schema

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INSERT INTO Station(ID, CITY, STATE, LAT_N, LONG_W)
VALUES(1, 'Austin', 'TX', 30, 98);
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Correctly accepted by the schema

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Correctly rejected by the schema

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INSERT INTO Station(ID, CITY, STATE, LAT_N, LONG_W)
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Industry advice

Destroying database consistency can have huge cost implications

Mutation Analysis

Once a test suite has been created, its fault finding capability can be estimated with mutation analysis.

For relational database schema testing, mutants are created by making small changes to the schema

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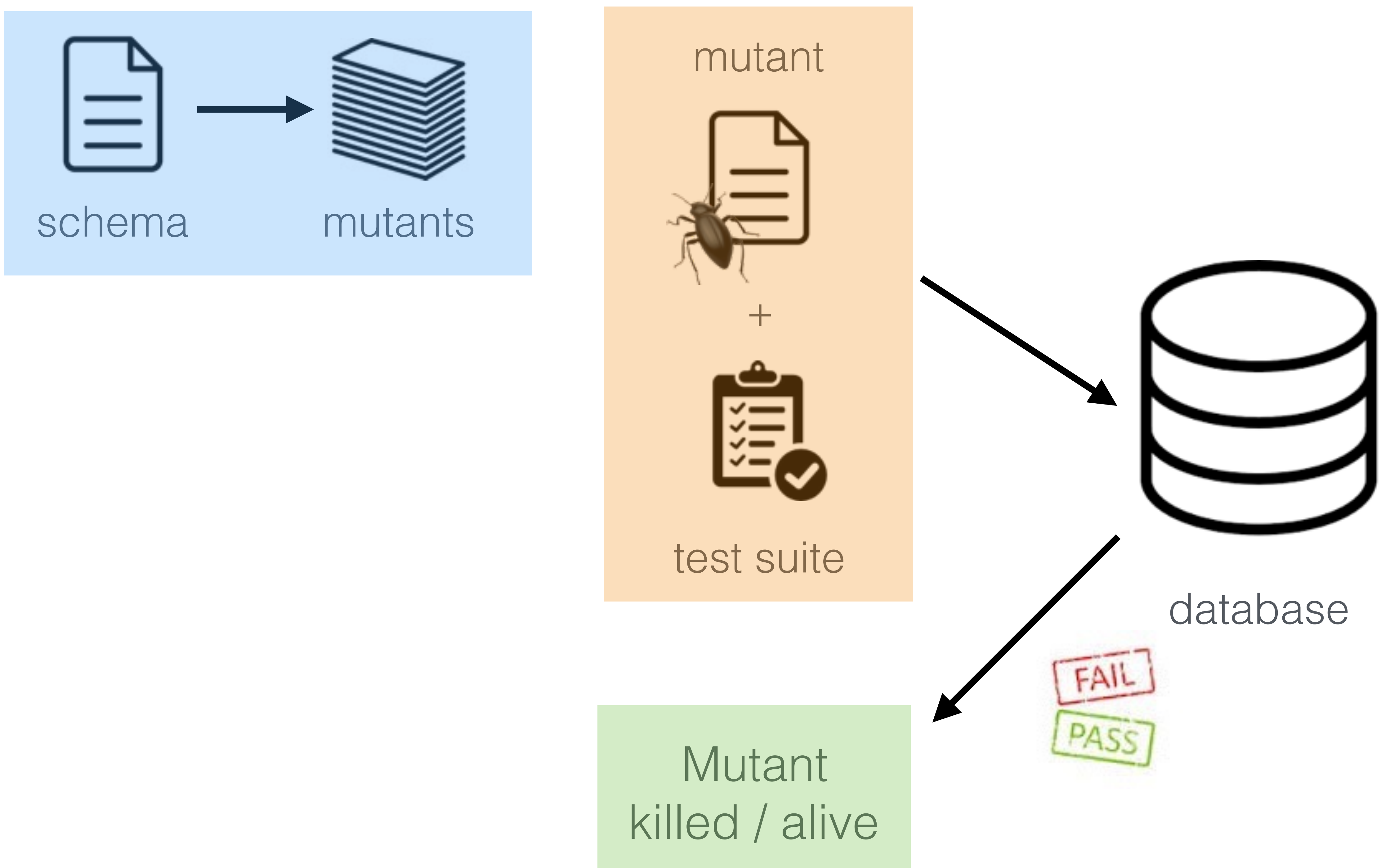

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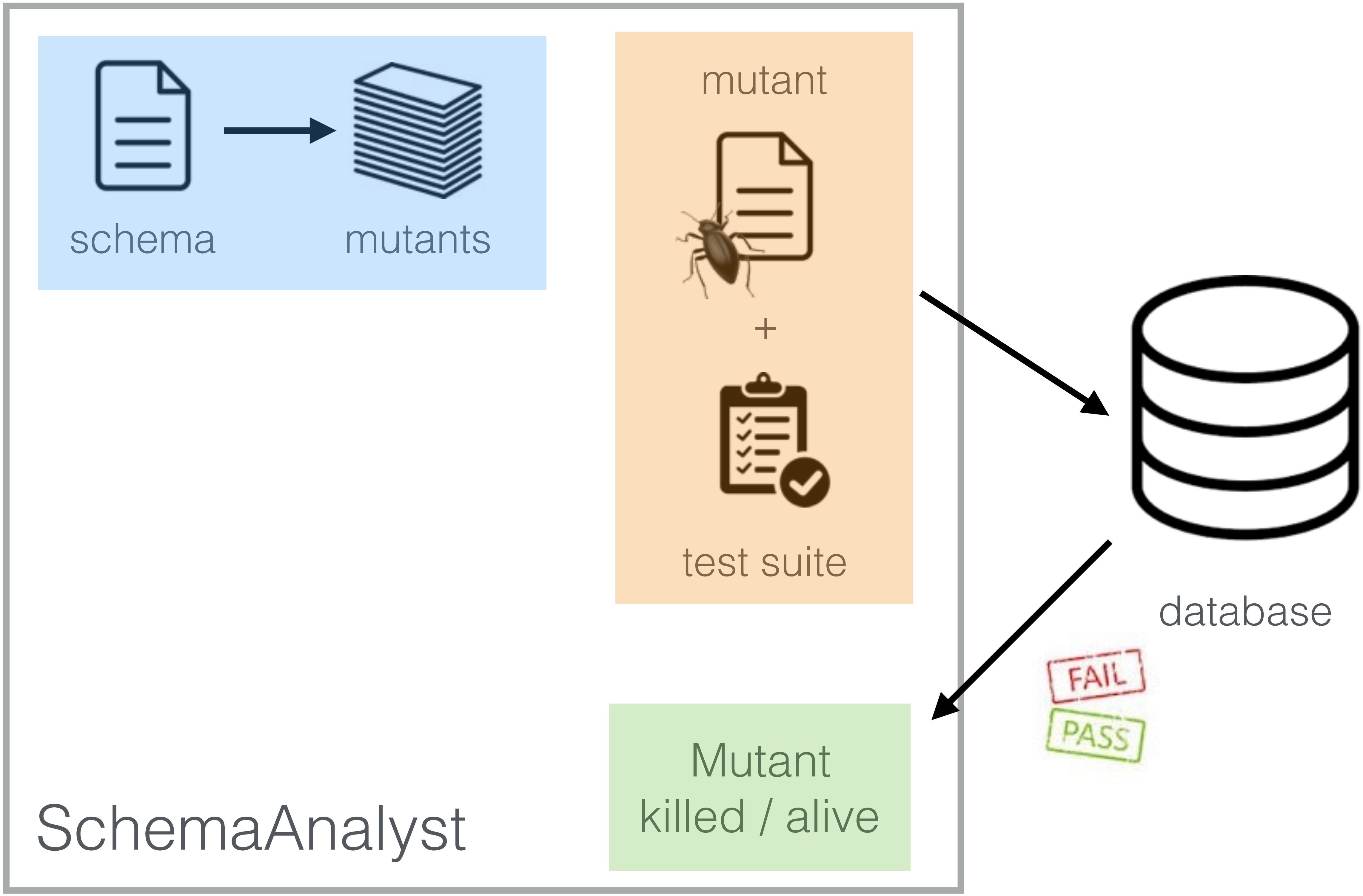

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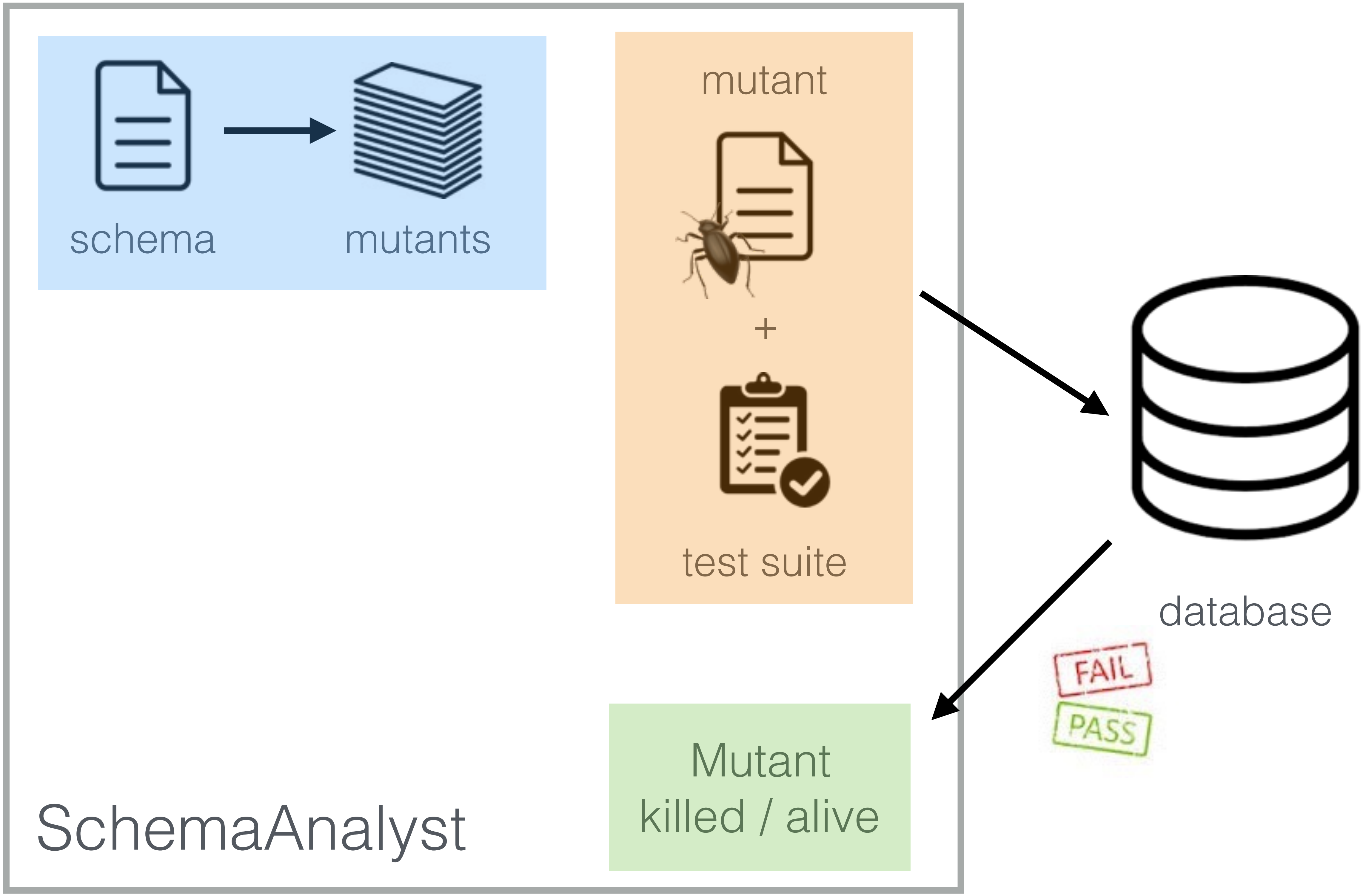

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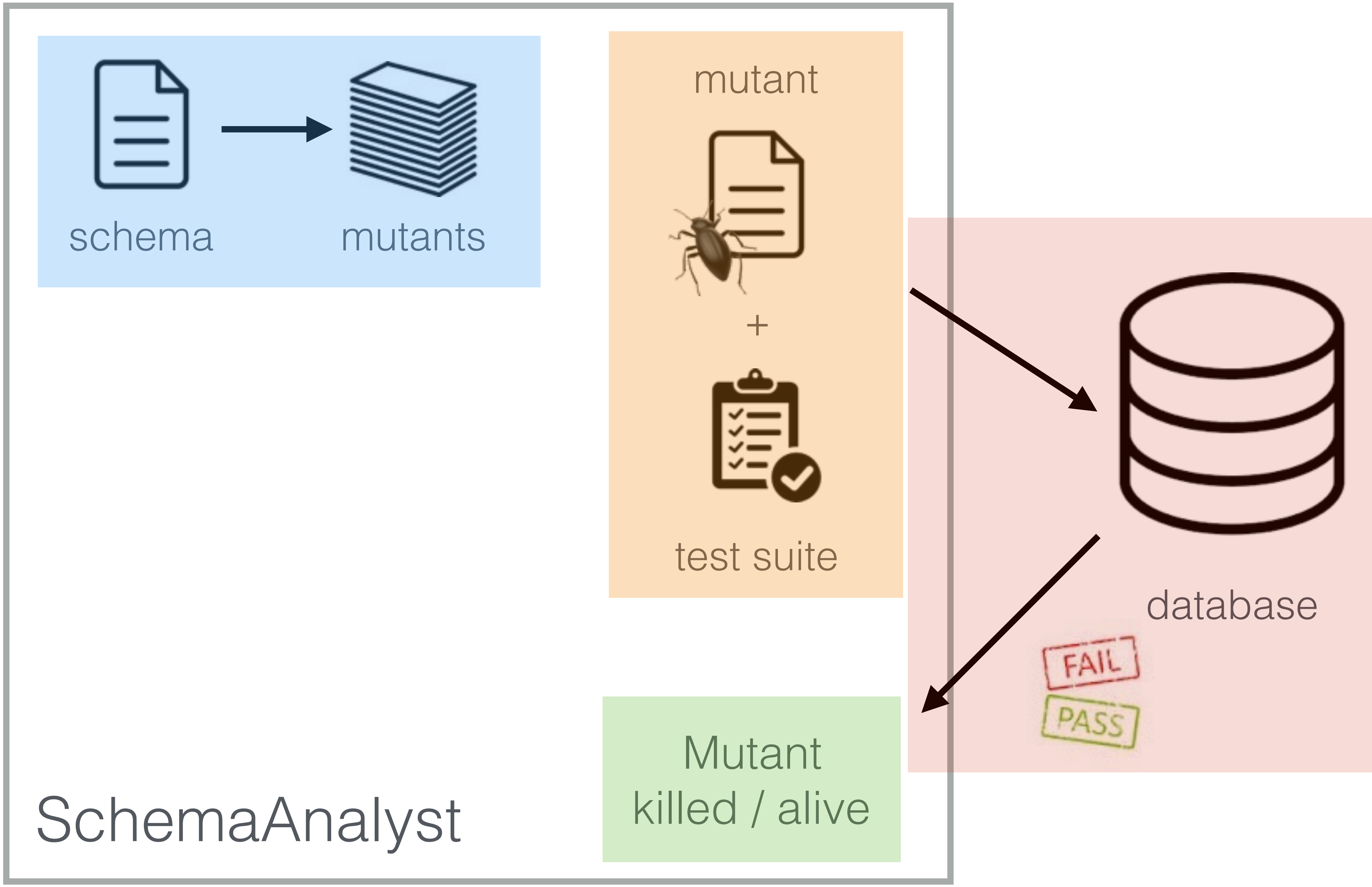

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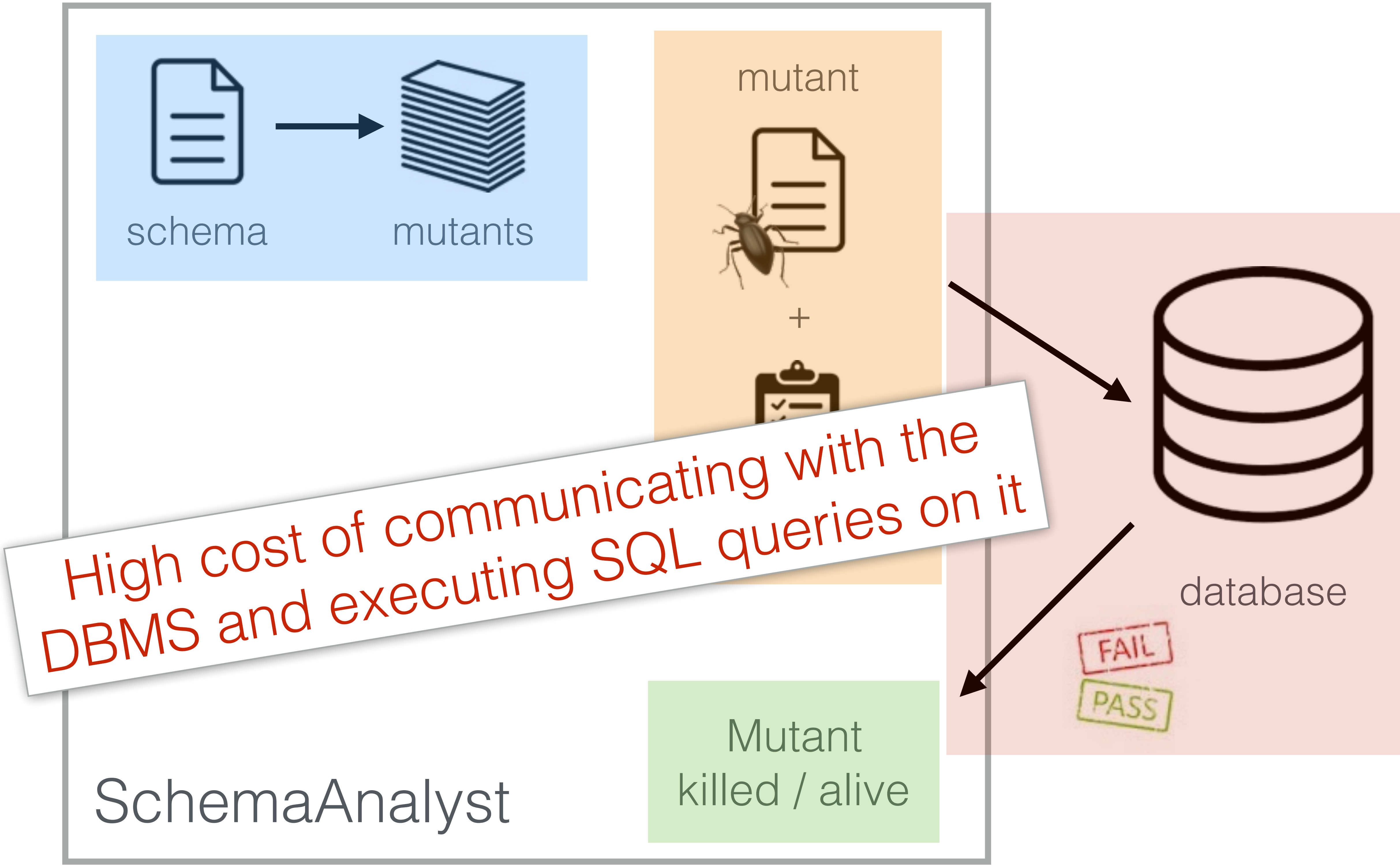
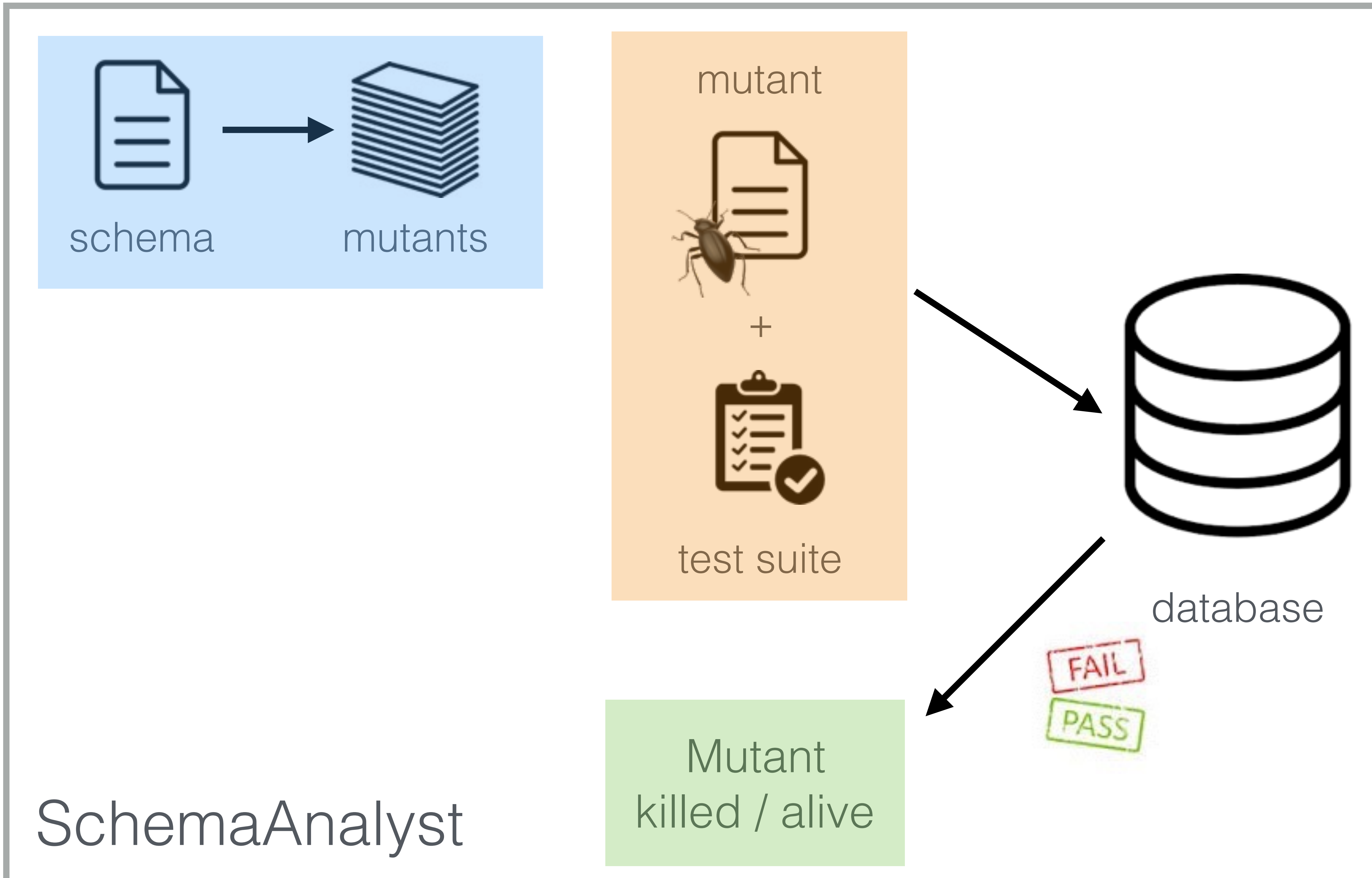


Reducing the Cost



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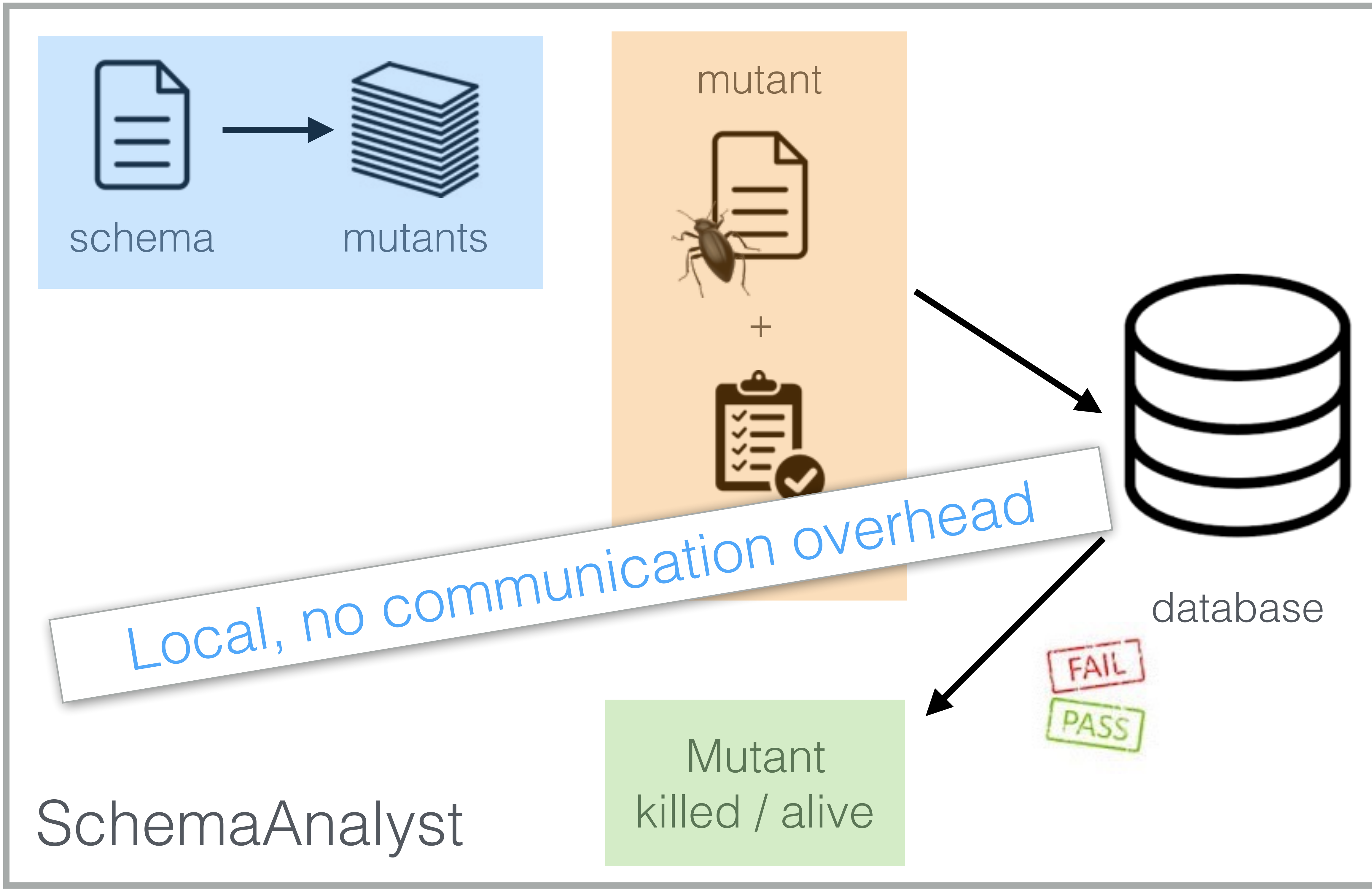

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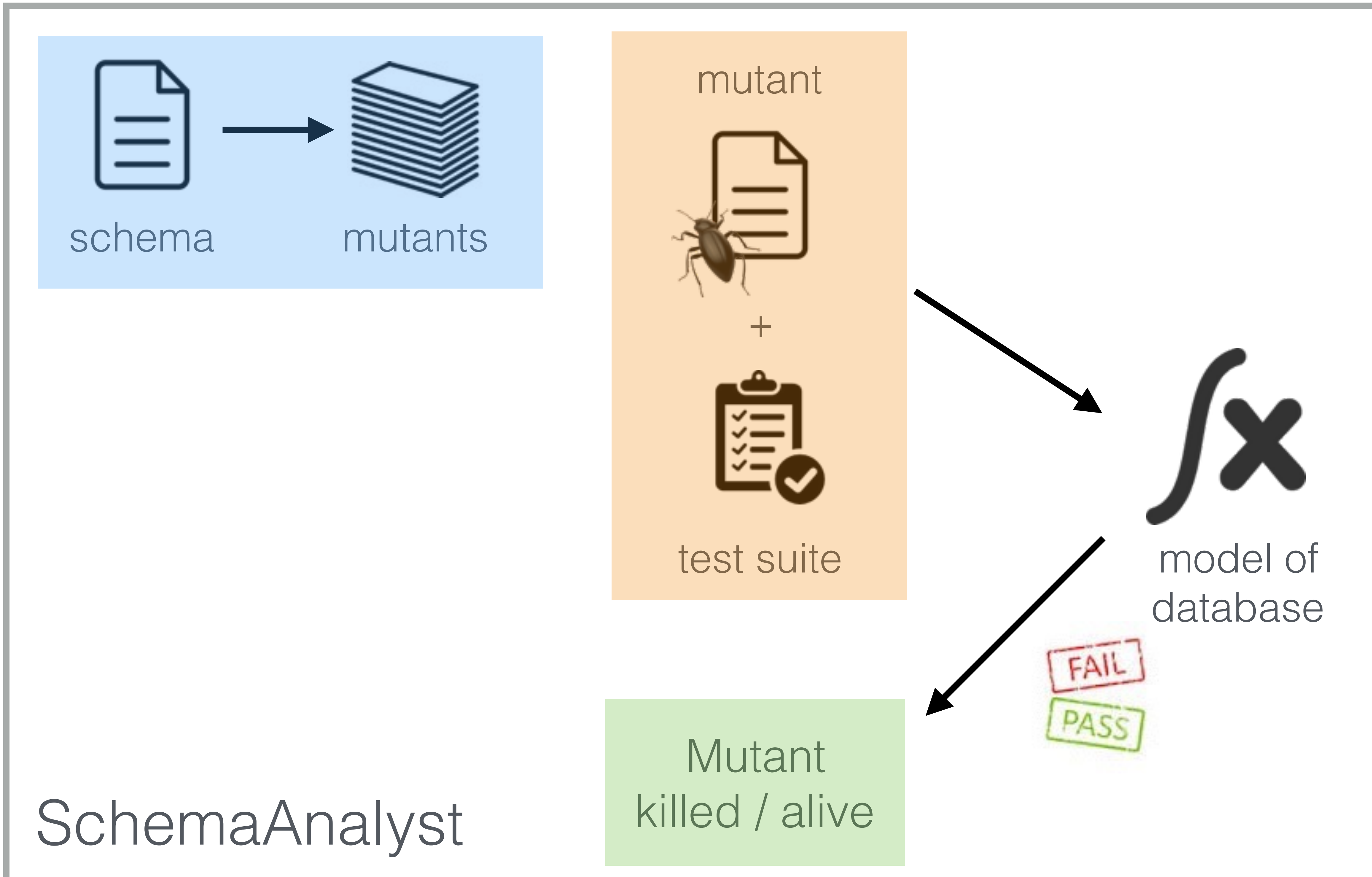

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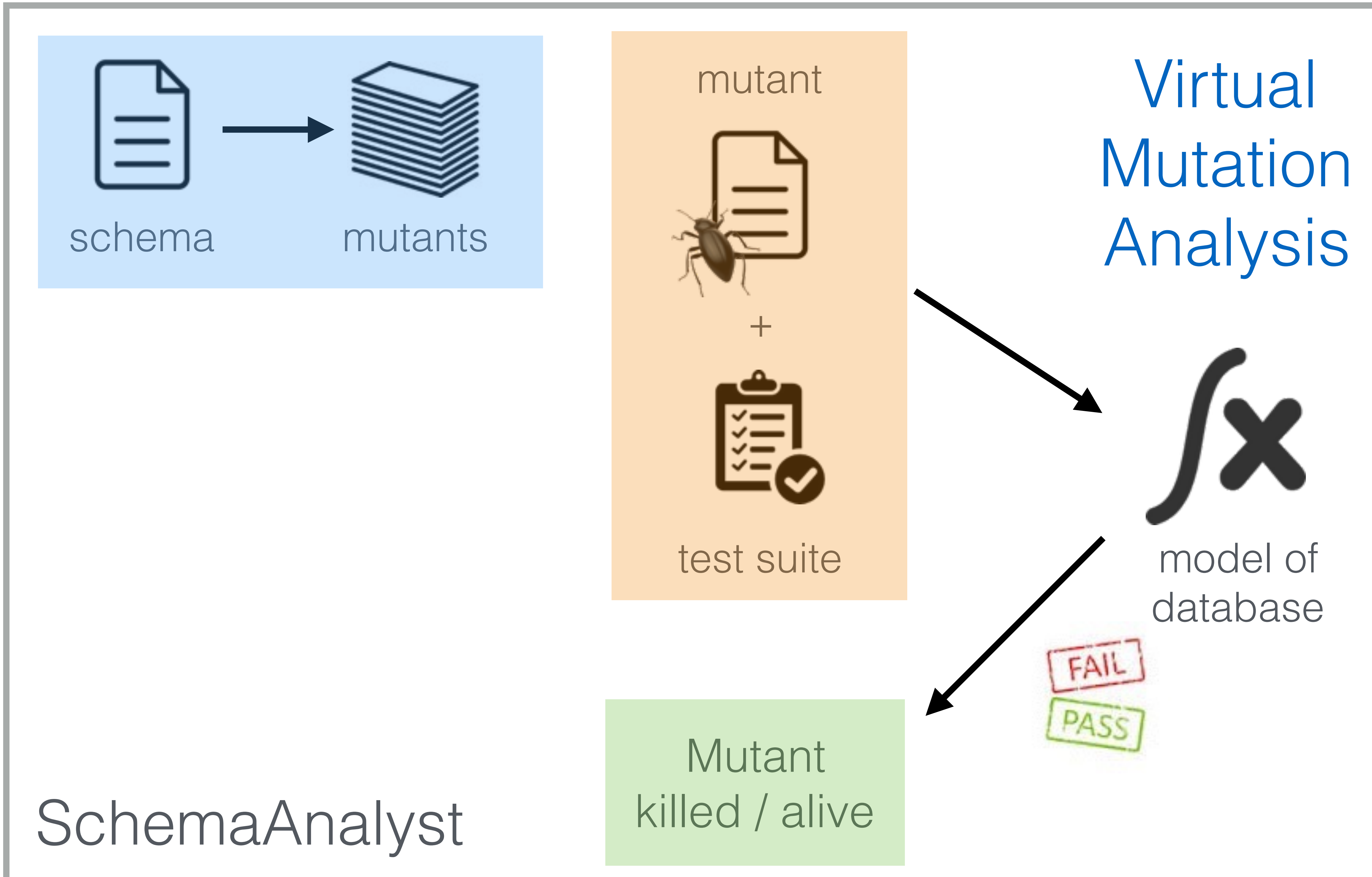

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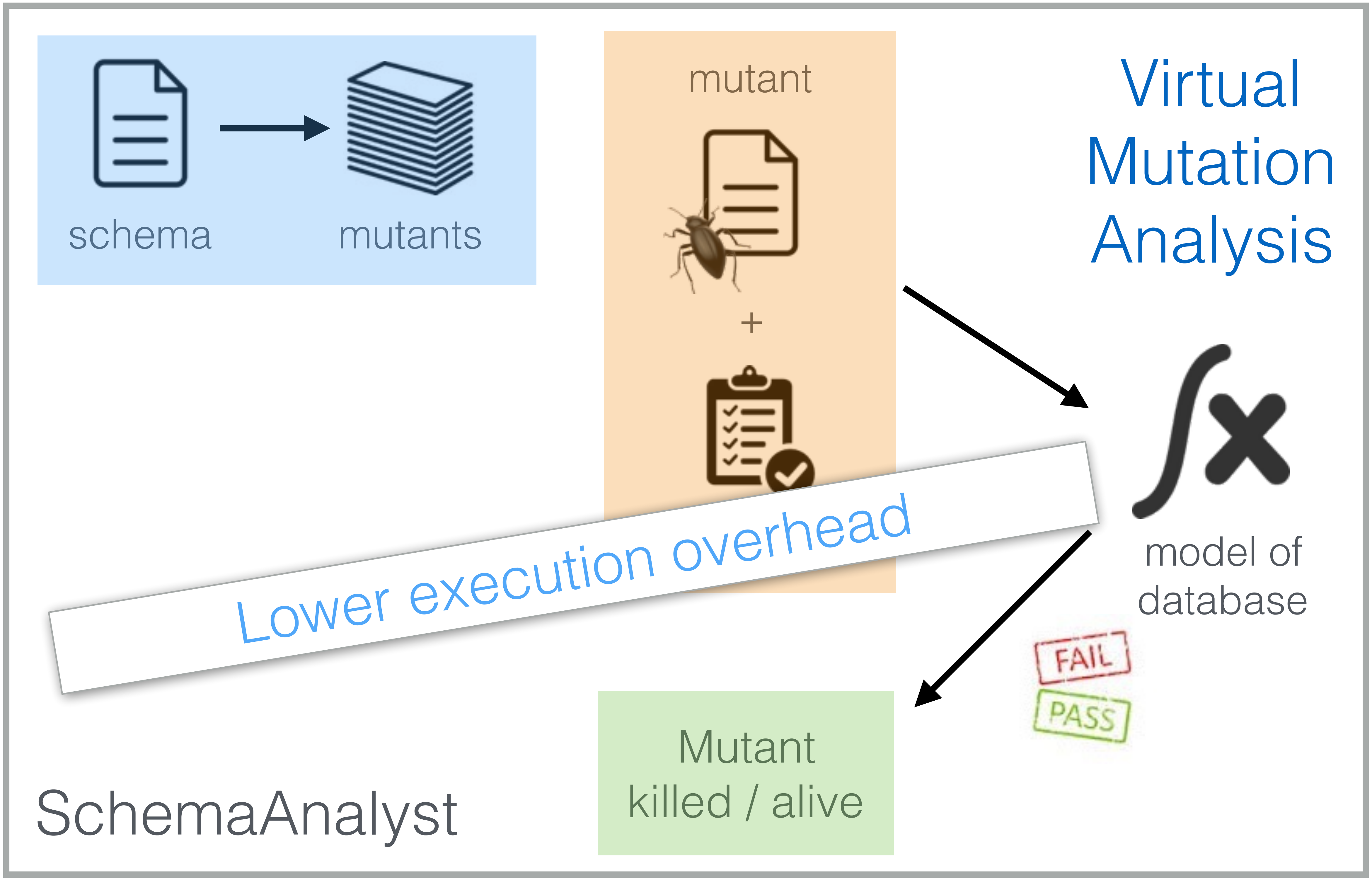

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Form an acceptance predicate for the table:

ap = icp1 ∧ icp2 ∧ icp3 ∧ icp4 ∧ icp5

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True when DBMS would accept the data

False otherwise

Virtual DBMS Models

PostgreSQL

SQLite

HyperSQL

HSQLDB - 100% Java Database

Empirical Study

RQ1. What is the relative efficiency of the virtual approach?

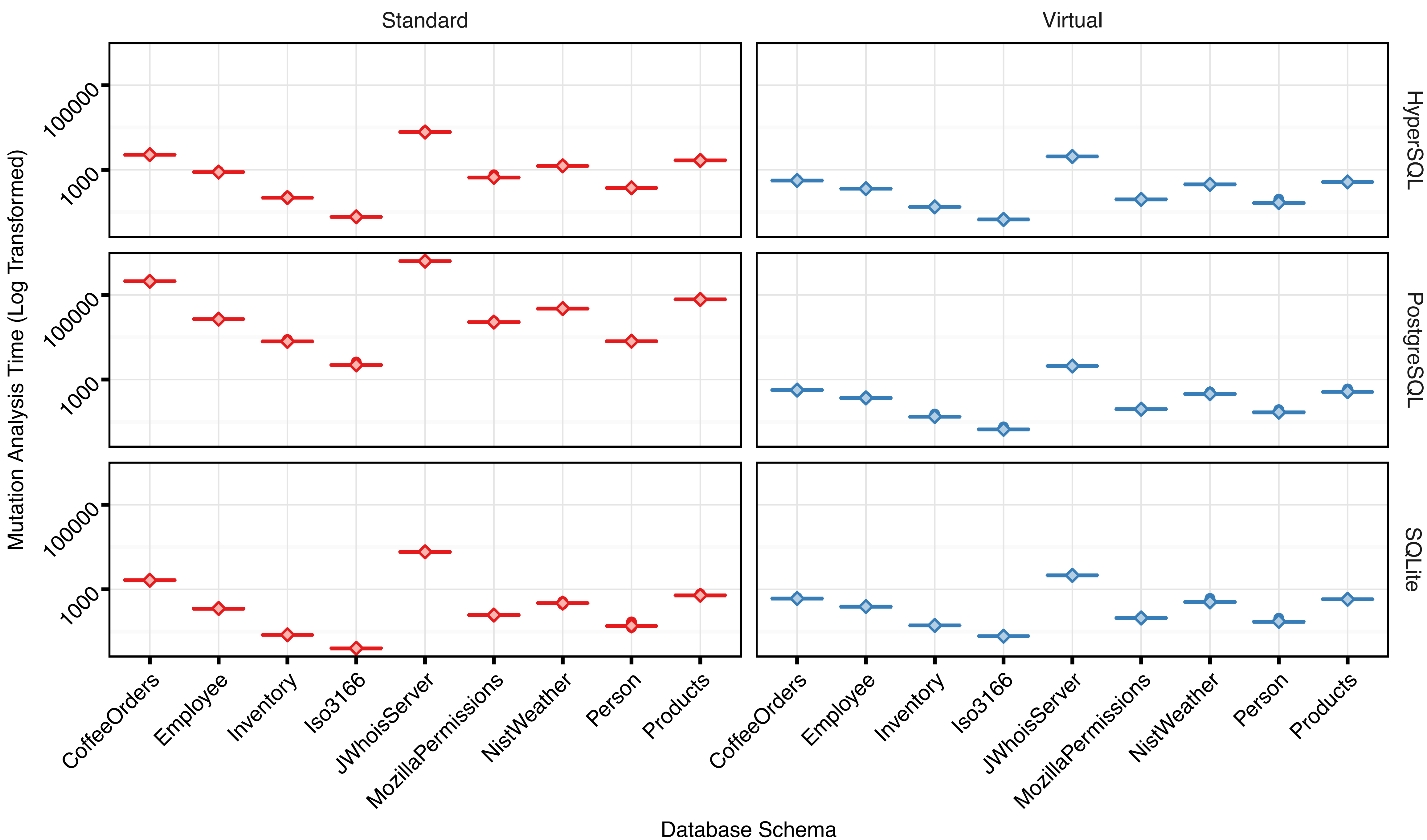
RQ2. What are the time savings?

RQ3. How do mutation scores compare when the standard approach is run for as long as the virtual one?

Subject Schemas

Schema	Tables	Columns	Checks	Foreign Keys	Not Nulls	Primary Keys	Uniques	$\sum$ Constraints
CoffeeOrders	5	20	0	4	10	5	0	19
Employee	1	7	3	0	0	1	0	4
Inventory	1	4	0	0	0	1	1	2
Iso3166	1	3	0	0	2	1	0	3
JWhoisServer	6	49	0	0	44	6	0	50
MozillaPermissions	1	8	0	0	0	1	0	1
NistWeather	2	9	5	1	5	2	0	13
Person	1	5	1	0	5	1	0	7
Products	3	9	4	2	5	3	0	14
Total	21	114	13	7	71	21	1	113

RQ1: Efficiency



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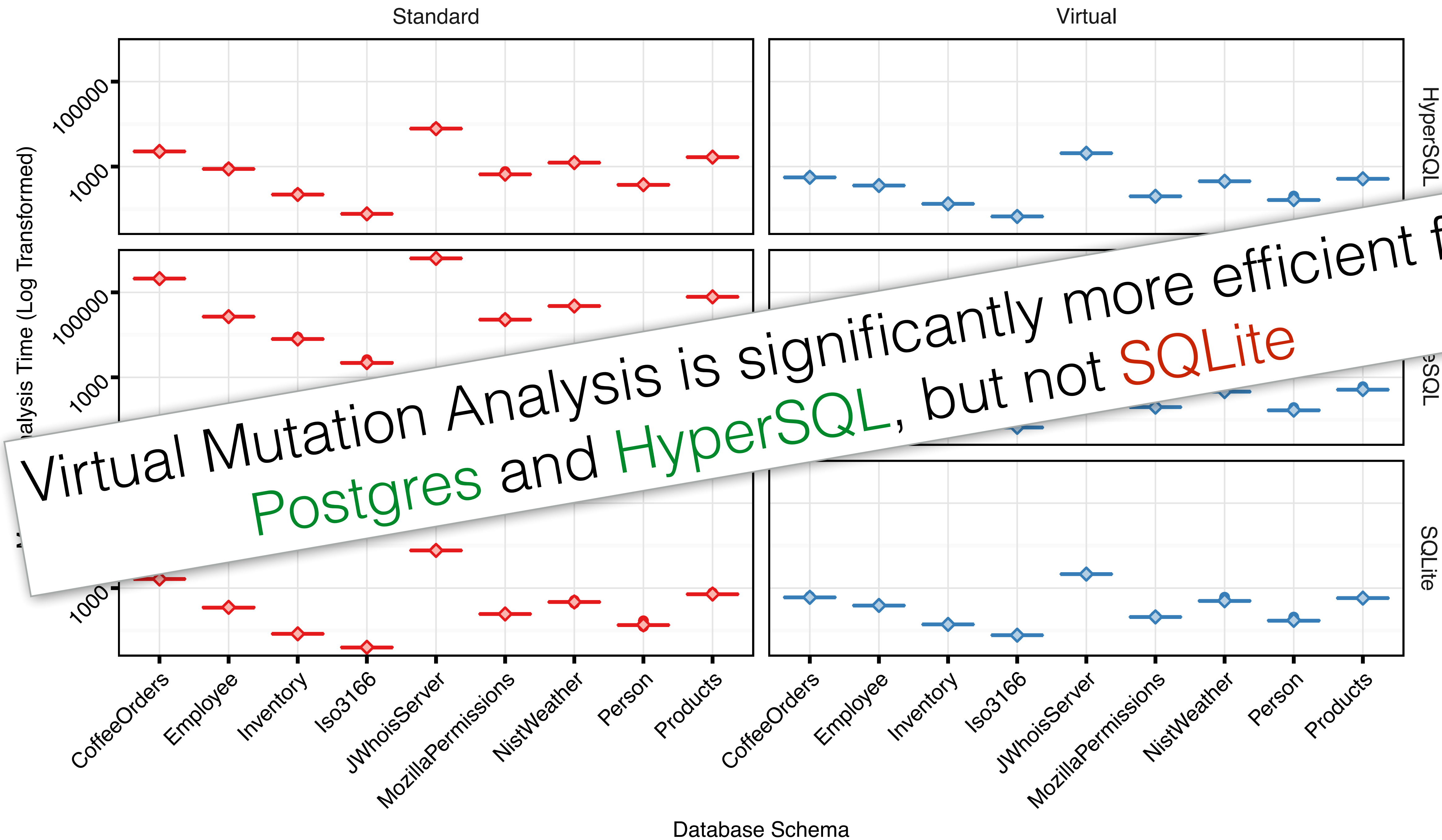
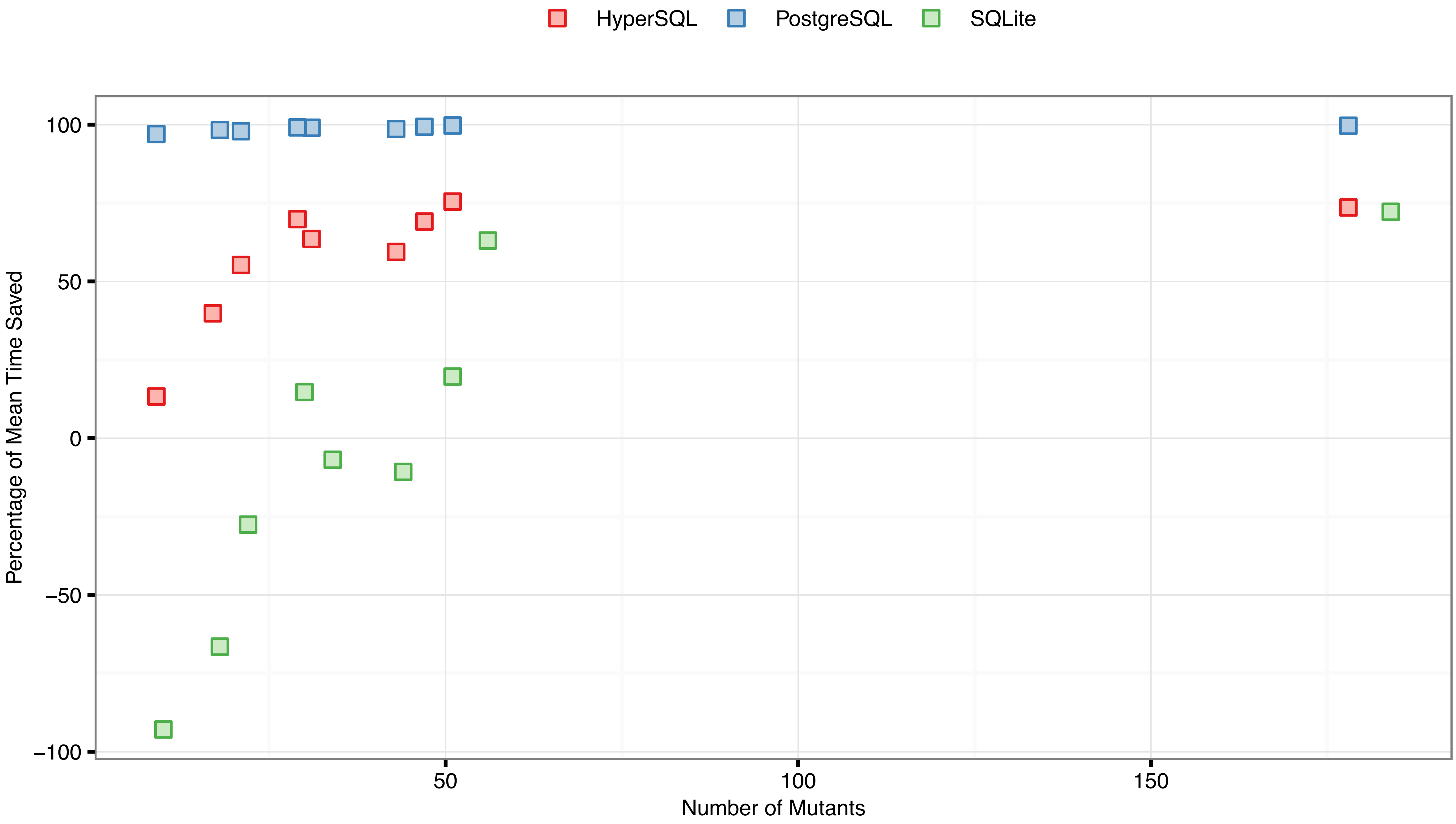


Virtual Mutation Analysis is significantly more efficient for Postgres and HyperSQL, but not SQLite

RQ2: Time Savings



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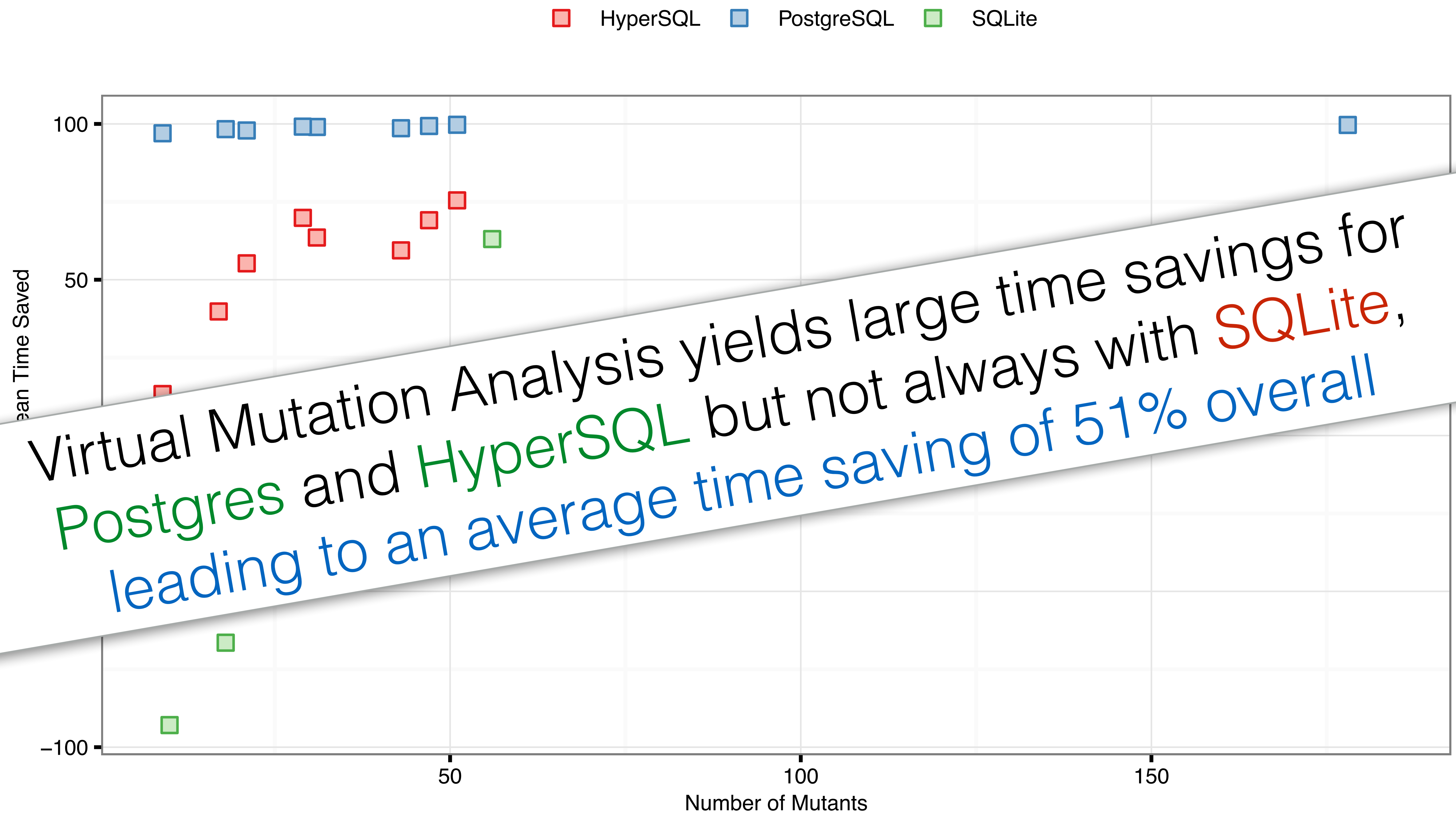
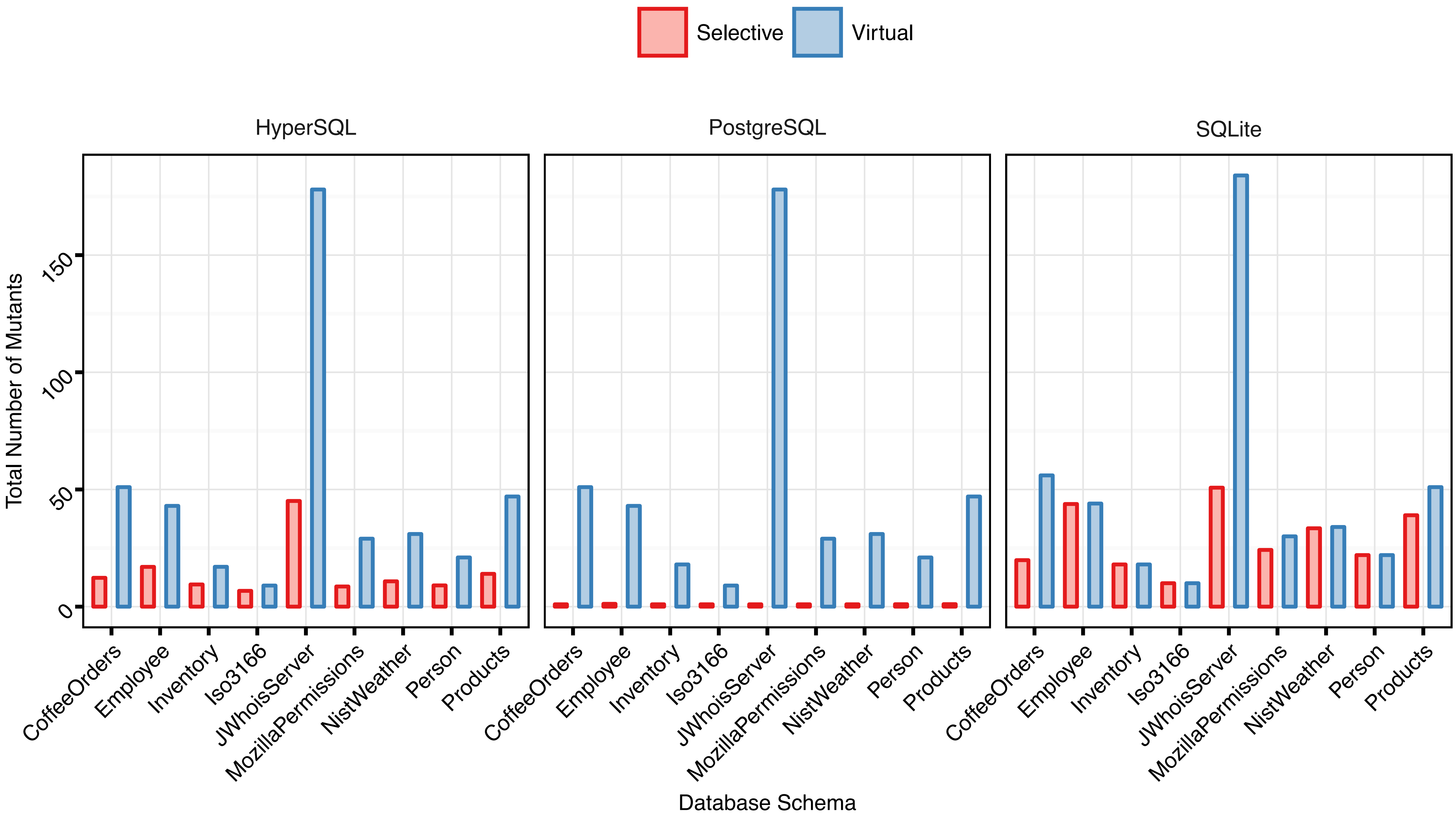


Virtual Mutation Analysis yields large time savings for Postgres and HyperSQL but not always with SQLite, leading to an average time saving of 51% overall

RQ3: Comparison



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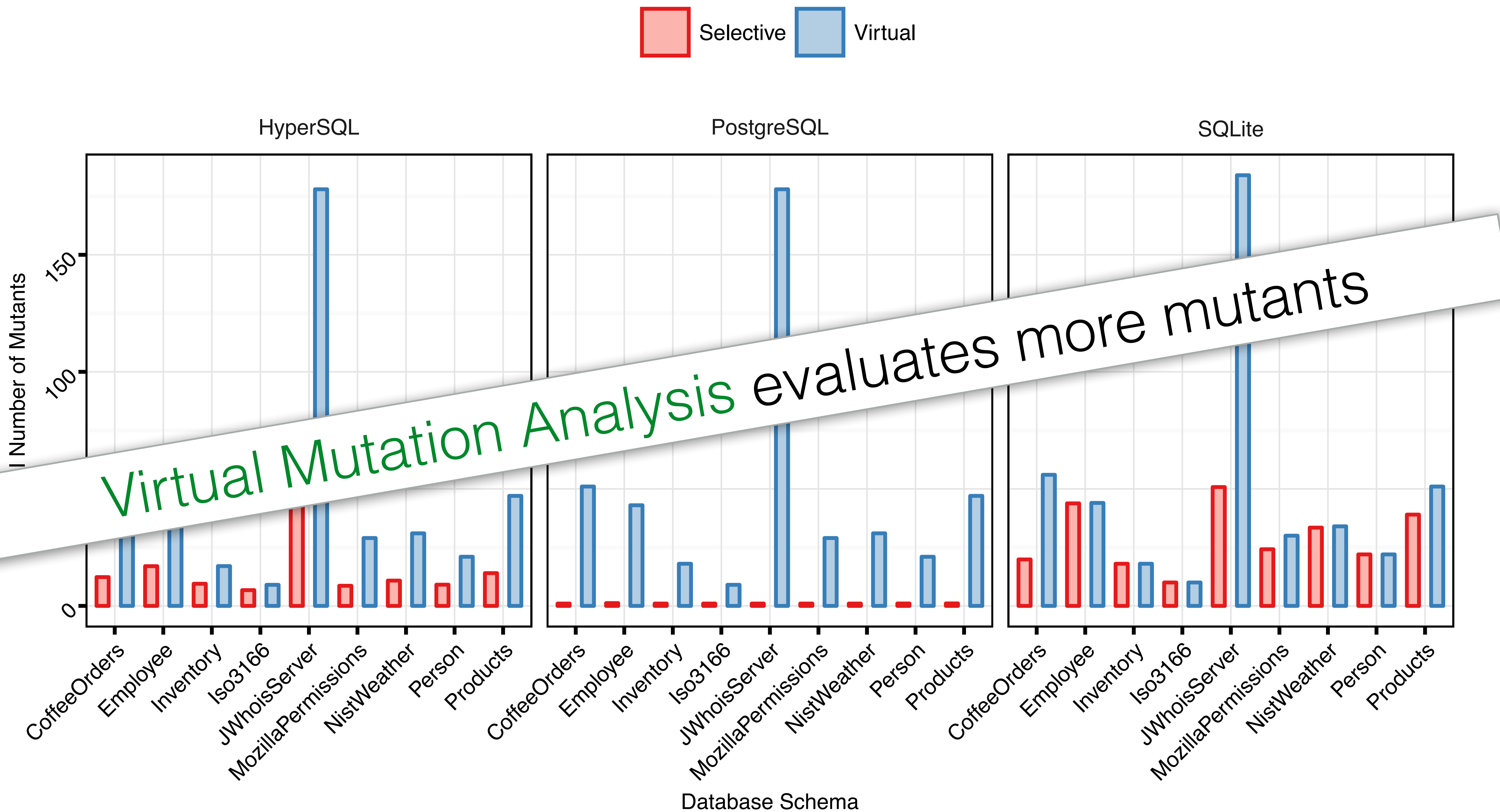

Virtual Mutation Analysis evaluates more mutants

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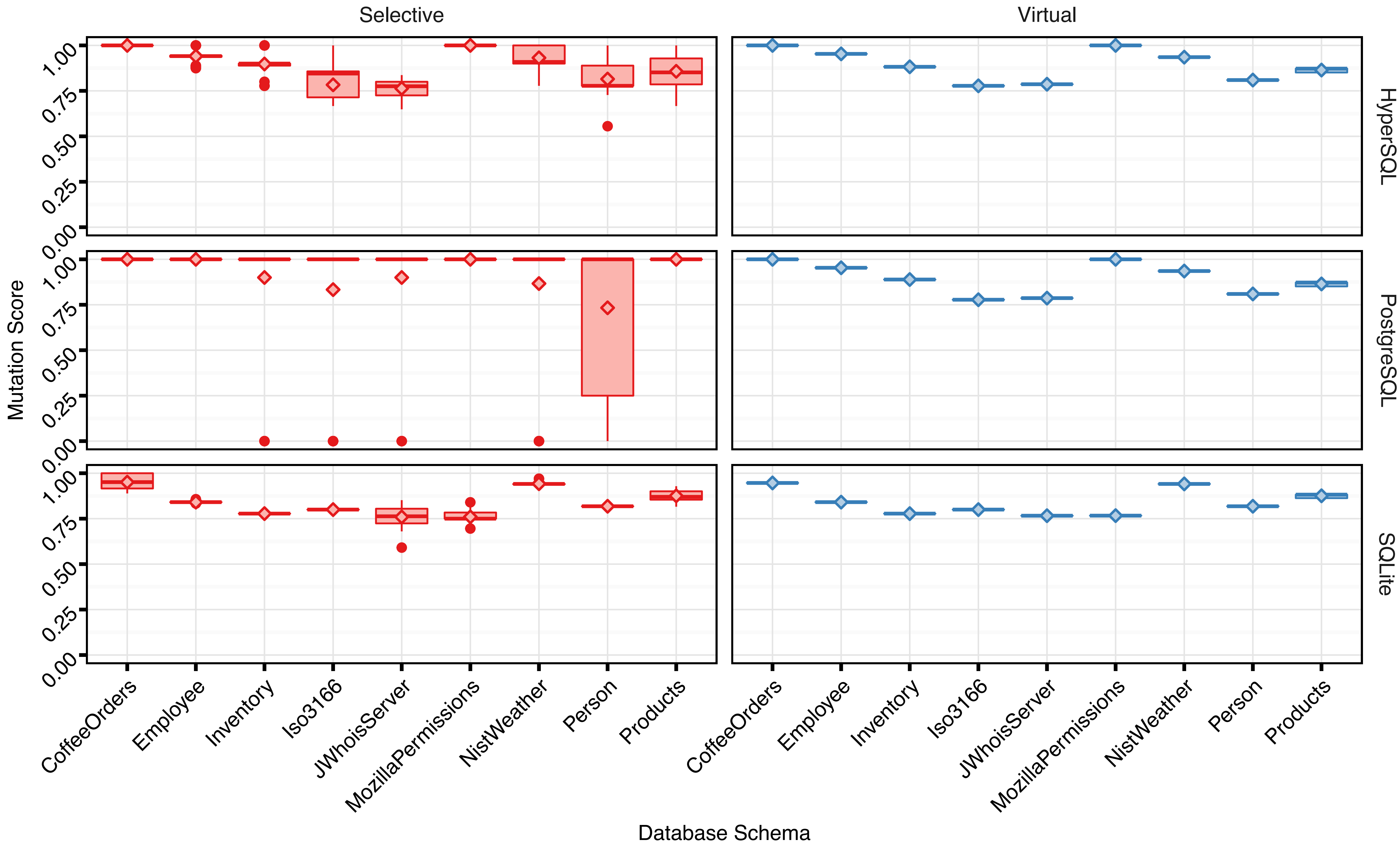

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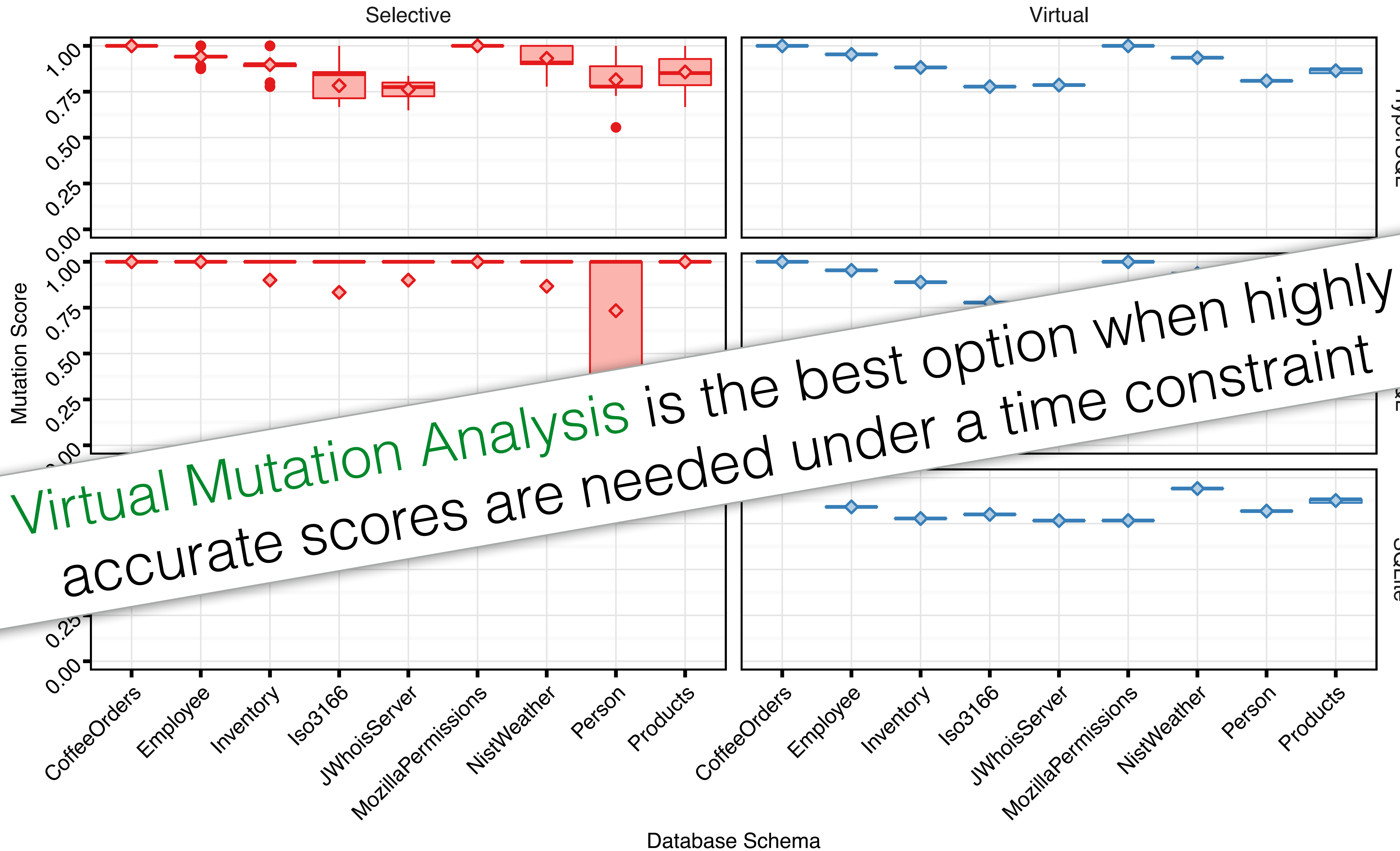

Virtual Mutation Analysis is the best option when highly accurate scores are needed under a time constraint

Conclusions

Virtual Mutation Analysis Technique:

Removes the need to use a real DBMS for relational database schema mutation testing

More cost-effective while still being accurate:

- More efficient for 22 of 27 configurations studied
- Yields time savings of 13 to 99%