An Adventure in Data Modeling

The Entity-Attribute-Value (EAV) Data Model

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Agenda

- Introduction
- The story
  - The original data model
  - Implementing the Entity-Attribute-Value (EAV) data model
  - Problems
  - Workarounds
- Please ask questions at any time!

Introduction

- Employed by  EDB
  `https://enterprisedb.com`
- PostgreSQL® Major Contributor
- Director at United States PostgreSQL® Association
  `https://postgresql.us`
- Portland PostgreSQL® Users Group
  `https://meetup.com/pdxpug/`

Why am I here?

Tell a PostgreSQL® performance story around the experiences with the evolution of the data model around a marketing company's customer information, where there was stumbling along the way, and how we carried on.

- Implementing the EAV data model
- Living with the EAV data model
- Share what was learned
  - Spoiler alert: don't be hasty
  - It's a database anti-pattern

Once upon a time...

(Before getting into the EAV data model...)

(Sometime before 2010...)

The customer's data

Per customer customize information about their members, e.g.:

- e-mail address
- first name
- last name
- favorite database

The original data model

- Horizontally partitioned data by customer using table inheritance
- 12+ child tables created per customer - only 1 table contained person information
- Exporting person information was fast and easy - this is the primary benchmark

Example: Exporting person information

A commonly performed task is to create a CSV file:

email	first_name	last_name	favorite_dbms
markwkm at postgresql.org	Mark	Wong	PostgreSQL
mark.wong at enterprisedb.com	Mark	Wong	WarehousePG

```
COPY persons_5432
TO 'persons-5432.csv' (FORMAT CSV);
```

A table with 1 million rows can be expected to complete within seconds.

What was wrong?

Other aspects of the system was under a lot of stress:

- Over 40,000 customers in the system
- One million+ objects in the system (tables, indexes, etc.)
- Hard to mine data i.e. generate reports
- Hard to administer database system
  - ALTER TABLE to add new attribute to track
  - Database backups

Problems with simple data mining

If simple queries can't run, complex queries definitely can't run:

- How many persons are being tracked?
- Getting counts from the parent tables would need 40,000 locks, one per child table
- More complex queries would start adding tables to join, increasing locks to be taken

Problems with database backups

Is an RPO (Recovery Point Objective) greater than a day ok?

- Backups with `pg_dump` takes more than whole day
- Less than 1 terabyte of data

Time to do something **drama**tic!

Major design changes

Highlights:

- Horizontally partition the database into a fixed number of tables to reduce the number of database objects
  - 40,000 partitions reduced down to 1,000
  - Approximately 1 GB of data per partition
- Developed homegrown Python middleware layer between Web front-end and database systems
- Database schema refactor: `persons` table converted to EAV data model

Entity-attribute-value (EAV) model is a data model to describe entities where the number of attributes (properties, parameters) that can be used to describe them is potentially vast, but the number that will actually apply to a given entity is relatively modest.

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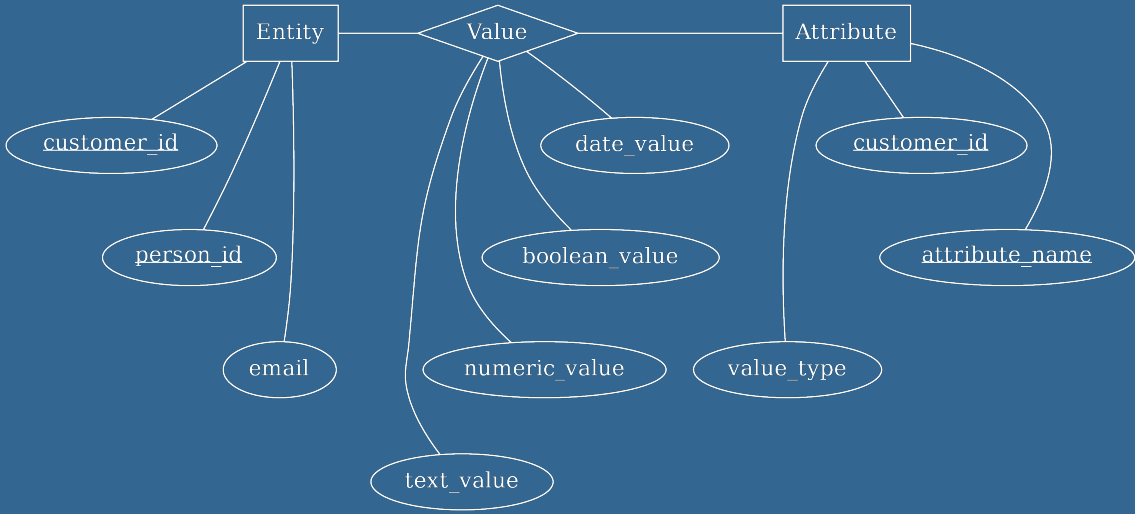
EAV is also known as object-attribute-value model, vertical database model and open schema.

`https://en.wikipedia.org/wiki/Entity-attribute-value_model`

EAV Entity-Relationship Diagram



What was known before rolling out EAV

- Pros
  - Still a simple three table model - even though previously 1 table
  - Can add attributes with DML statements instead of DDL statements
    - Avoid `ALTER TABLE` statements - expensive heavy table locks
    - Use `INSERT`, `UPDATE` or `DELETE` - lighter finer grained row locks
- Cons
  - Data will need to be:
    - queried differently
    - transformed somewhere i.e. pivoted
  - Data type checking more complex, either implemented by:
    - multiple tables
    - multiple columns (opted for this)

The need to pivot data

Using EAV pivoted the data from the original model:

email	attribute_name	value
markwkm at postgresql.org	first_name	Mark
markwkm at postgresql.org	last_name	Wong
markwkm at postgresql.org	favorite_database	PostgreSQL

Need to pivot it back:

email	first_name	last_name	favorite_dbms
markwkm at postgresql.org	Mark	Wong	PostgreSQL

That doesn't look so bad, right?

Sample of table sizes

Row counts are more significant than data size:

customer	entity	attribute	value
1	1,000,000	120	120,000,000
2	2,000,000	50	100,000,000
3	700,000	100	700,000

How long it takes to export data?

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All exports failed for the largest customers!

Uh oh, what's going wrong?

Some customer can't export their data anymore, something is taking too long:

- PostgreSQL® statement timeouts? Disable statement timeout?
- Web server HTTP timeouts? Don't go through the Web server?
- Network switches TCP/IP idle timeouts?
- Get closer to the database server?

Application developers please take note!

Homegrown Python middleware layer was pivoting data:

customer	entity	attribute	value	execution time
1	1,000,000	120	120,000,000	DNF
2	2,000,000	50	100,000,000	DNF
3	700,000	100	700,000	4 hours

Did **N**ot **F**inish

Where to start...

As a database person suspicious that homegrown code can pivot data faster than a database management system:

- Have the database return pivoted data
- The *tablefunc* extension can pivot data with the *crosstab()* function
- `https://www.postgresql.org/docs/current/static/tablefunc.html`

Brief simpilified *crosstab()* example

```
SELECT email, first_name, last_name, favorate_dbms
FROM entity LEFT OUTER JOIN
     crosstab (<sql>) AS ct(person_id BIGINT,
                            first_name TEXT,
                            last_name TEXT,
                            favorite_dbms TEXT)
        ON entity.person_id = ct.person_id
WHERE entity.customer_id = 5432;
```

Note: `<sql>` is the `SELECT` statement to retrieve data from the EAV model.

Is *crosstab()* a positive improvement?

Results with *crosstab()*

customer	entity	attribute	value	EAV execution time	*crosstab()* execution time
1	1,000,000	120	120,000,000	DNF	22 minutes
2	2,000,000	50	100,000,000	DNF	17 minutes
3	700,000	100	700,000	4 hours	10 minutes

Yay! Much Faster!

Business as usual, for now...

There are some trade-offs:

- ORMs do not natively abstract the database pivoting data (is this still true in 2025?)
- Small exports (in the 100's) now take a little longer
- Overall still slower than the original data model

Not all obstacles have been removed

After more testing, problems with EAV not fully addressed:

- *crosstab()* will fail with any customers with between 5 to 10 million persons
- Importing person data already facing similar performance challenges

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We still need to do better!

Biggest question at this juncture:
What if we remove this data from the PostgreSQL®?

Ok, I guess we can prototype another data model...**in PostgreSQL®**!

Exploring a non-relational data model

Try a key/value store:

- Use the PostgreSQL® *hstore* extension to proof a solution
  - This extension implements the *hstore* data type for storing sets of key/value pairs within a single PostgreSQL® value.
  - This can be useful in various scenarios, such as rows with many attributes that are rarely examined, or semi-structured data.
  - Keys and values are simply text strings.
- `https://www.postgresql.org/docs/current/hstore.html`

Cons to *hstore* data type

Noted before diving in:

- No strict types; everything is a string
- No referential integrity constraints
- Native support varies in higher level database connectivity libraries

This is *hstore*

Put the person's attribute values back into the **entity** table as the *hstore* column field. The key in field's key/value pair is the field name.

email	**hstore**
markwkm at postgresql.org	"first_name" => "Mark", "last_name" => "Wong", "favorite_database" => "PostgreSQL"

Example converting EAV to *hstore*

```
WITH u AS (
    WITH t AS (
        SELECT person_id, value.attribute_name,
        CASE WHEN value_type = 'text' THEN text_value
             WHEN value_type = 'numeric' THEN numeric_value::TEXT
             WHEN value_type = 'boolean' THEN boolean_value::TEXT
             WHEN value_type = 'date' THEN date_value::TEXT
             ELSE NULL END AS value
        FROM value, attribute
        WHERE value.attribute_name = attribute.attribute_name
    )
    SELECT person_id,
           string_agg(hstore(attribute_name, value)::TEXT, ',')::HSTORE AS hst
    FROM t GROUP BY member_id
)
UPDATE entity
SET attributes = hst
FROM u
WHERE u.person_id = member.person_id;
```

Exporting person information with *hstore*

```
COPY (
    SELECT email,
           attributes -> 'name_first' AS first_name,
           attributes -> 'name_last' AS last_name,
           attributes -> 'favorite_dbms' AS favorite_dbms
    FROM entity
    WHERE customer_id = 5432
) TO 'entity-5432.csv' (FORMAT CSV);
```

How fast is exporting person information with *hstore*?

Exporting member information is pretty fast

customer	persons	fields	values	EAV execution time	*crosstab()* execution time	*hstore* execution time
3	700,000	100	700,000	4 hours	10 minutes	15 seconds

Sorry, didn't time the other accounts... But now near the original export times!

Lessons learned

- Please try not to use the EAV data model - retrieving and inserting data is inefficient and performs poorly with under 1 million rows
- Do large data transformations in the database - Python code performance issues begins when pivoting millions+ of rows
- EAV increased on-disk usage by about 50% - varies by number of attributes
- If the EAV data model is already in use there are options to help get by:
  - *tablefunc* extension with the *crosstab()* data pivoting functions will help into millions of rows - in minutes
  - *hstore* data transformation can be done on-the-fly in seconds
- JSON was not yet a native data type in PostgreSQL® at the time of this adventure - similar experience expected as with *hstore*

Thank you!

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