ANALYTICS AND DATA SUMMIT 2020

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February 25-27, 2020

Hands-on Lab

Property Graph from scratch: data sources to graphs

by
Gianni Ceresa
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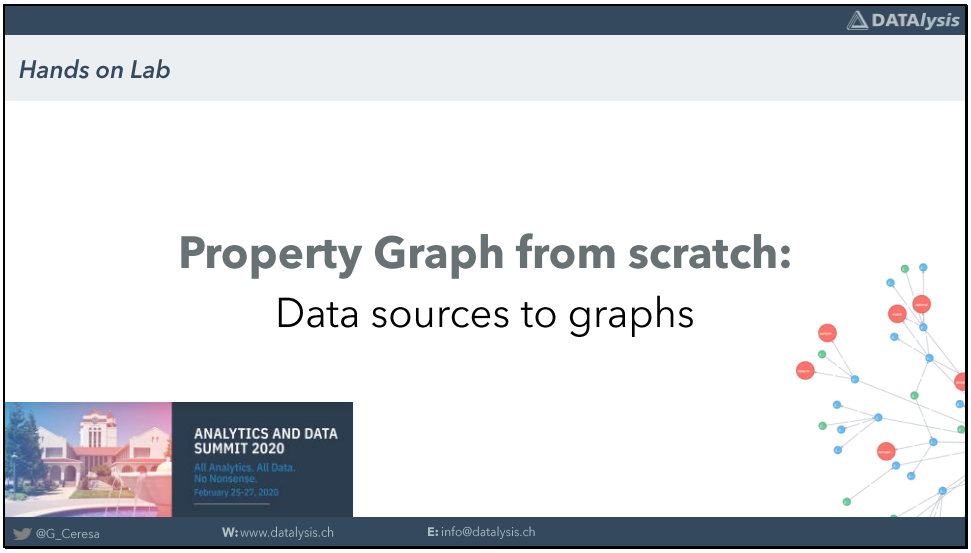
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Hands on Lab
Property Graph from scratch:
Data sources to graphs
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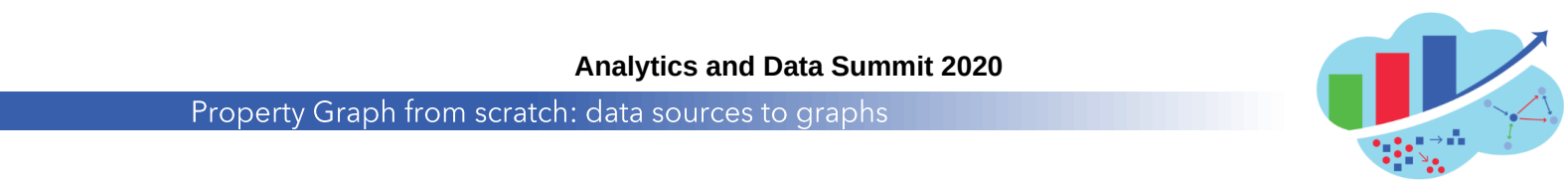

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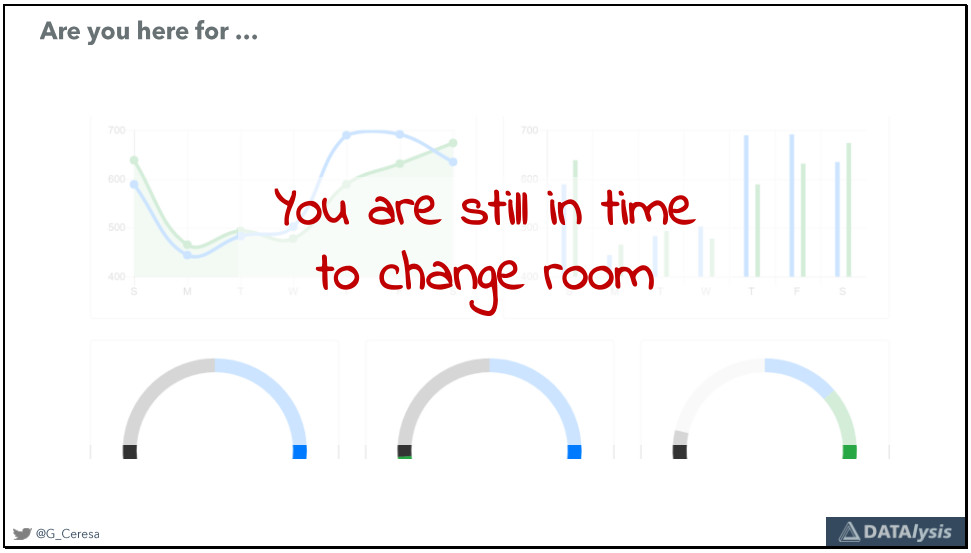
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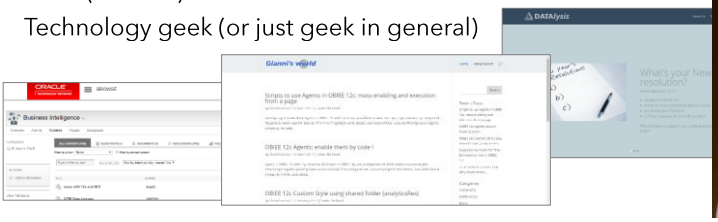

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Have a look at the Oracle ACE Program, the various levels, the directory where to search current ACEs and feel free to nominate somebody you believe deserves it or even yourself.

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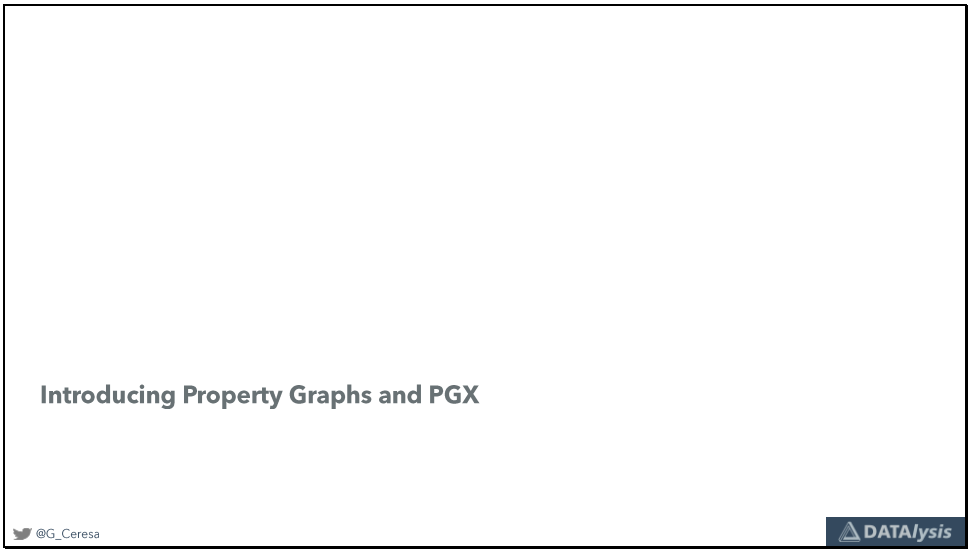

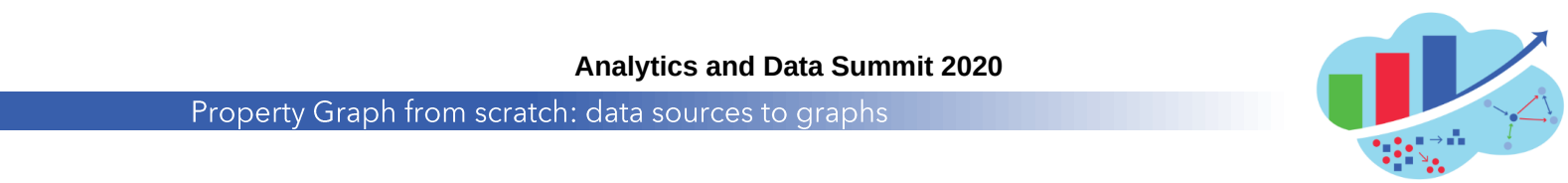

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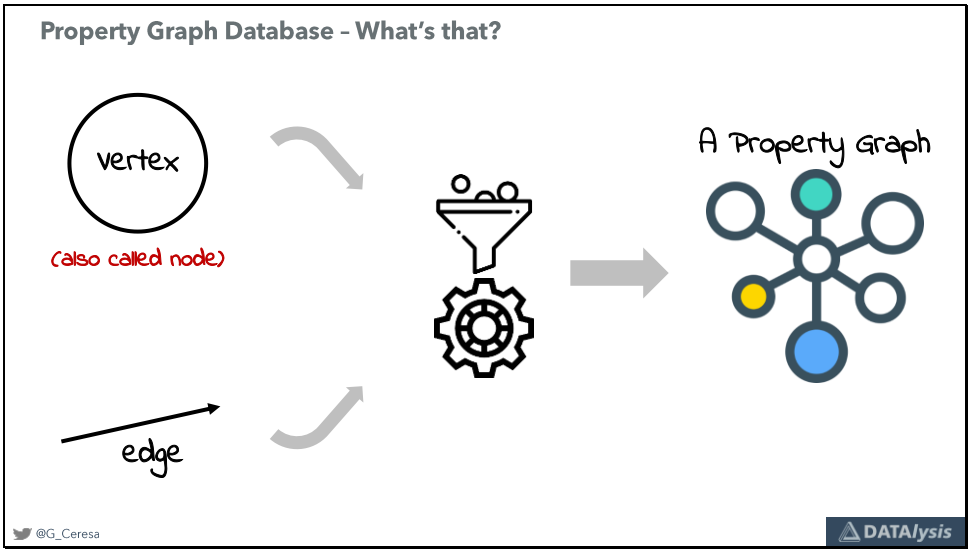
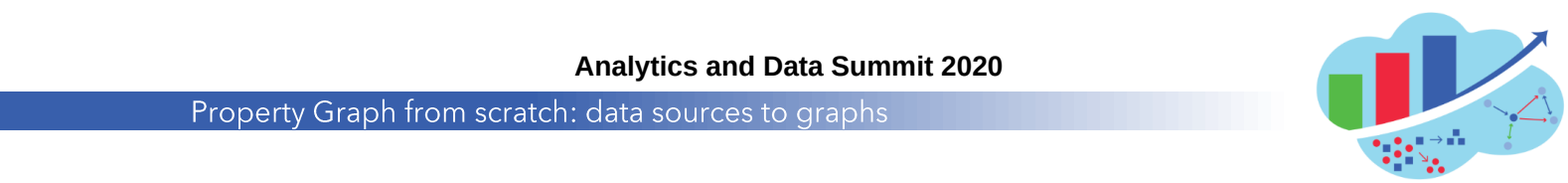


A Property Graph is composed by only 2 kind of objects: vertices (nodes) and edges.
Take some vertices, take some edges, mix all that together and done: you have a graph.



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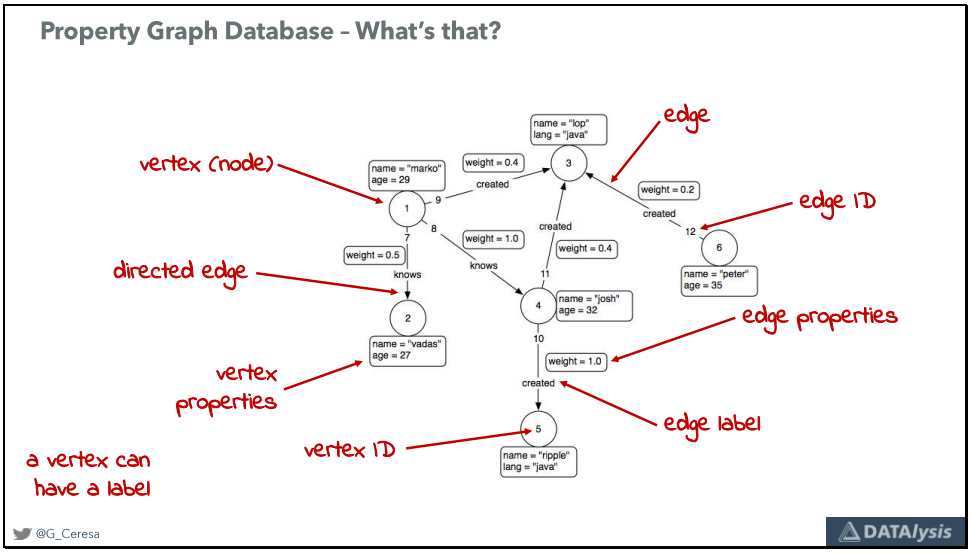
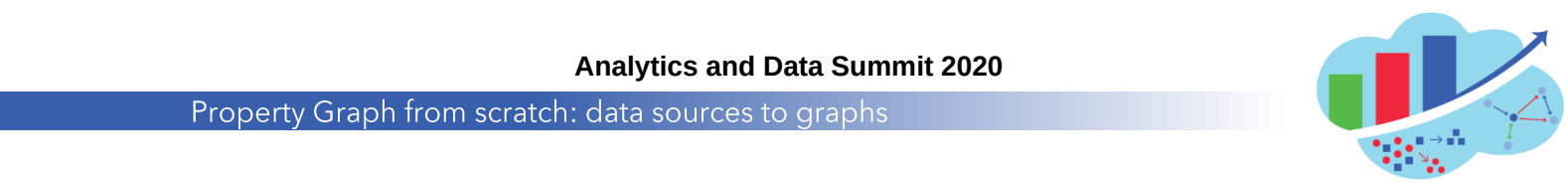


This is a visualization of an example graph: the 2 components, nodes and edges, are clearly visible.
Both have an ID to uniquely identify each element. Nodes can have a label, it isn't mandatory, and in Oracle they can also be more than one. A label is used to qualify the kind of node. For example it could be "customer" or "product" or whatever else.
Edges often have a label, but it isn't mandatory, and it's generally a verb to define the relationship connecting the 2 nodes.
Both nodes and edges can have properties. They are simply key-values entries and they are all independent one from the other. One node can have 10 properties, another 200, another none.



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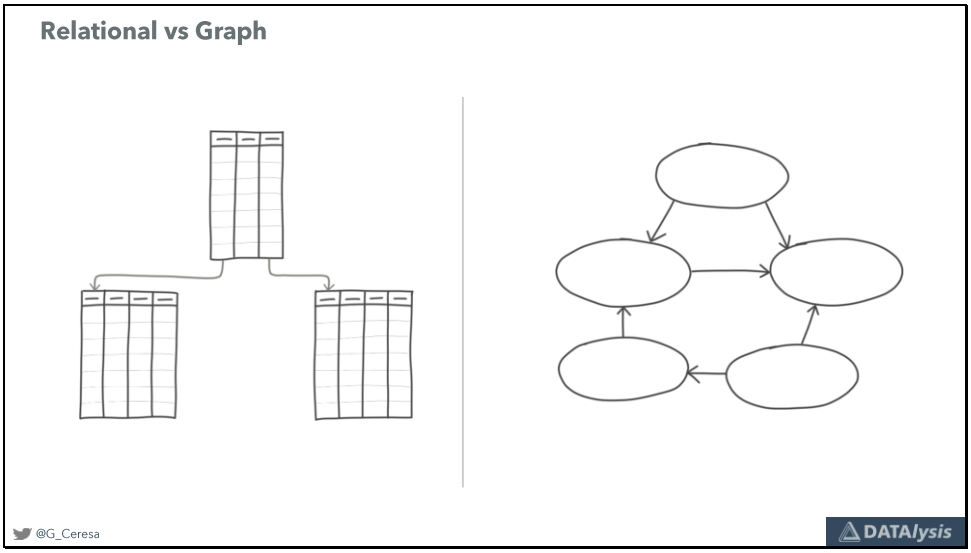
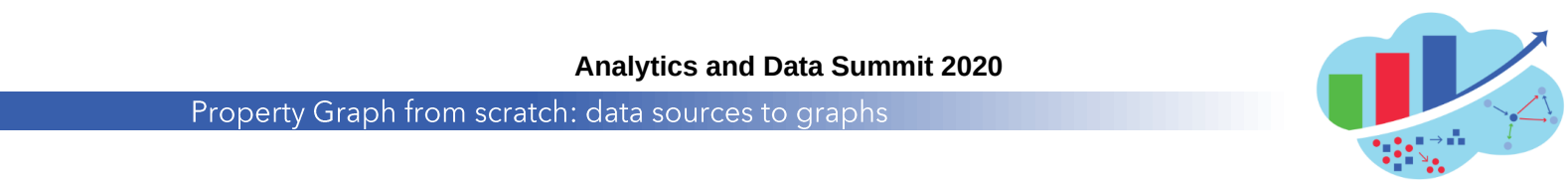


Some tables with joins, primary key – foreign key, between them.
Tables have a given set of columns.

The graph is some nodes and some edges.



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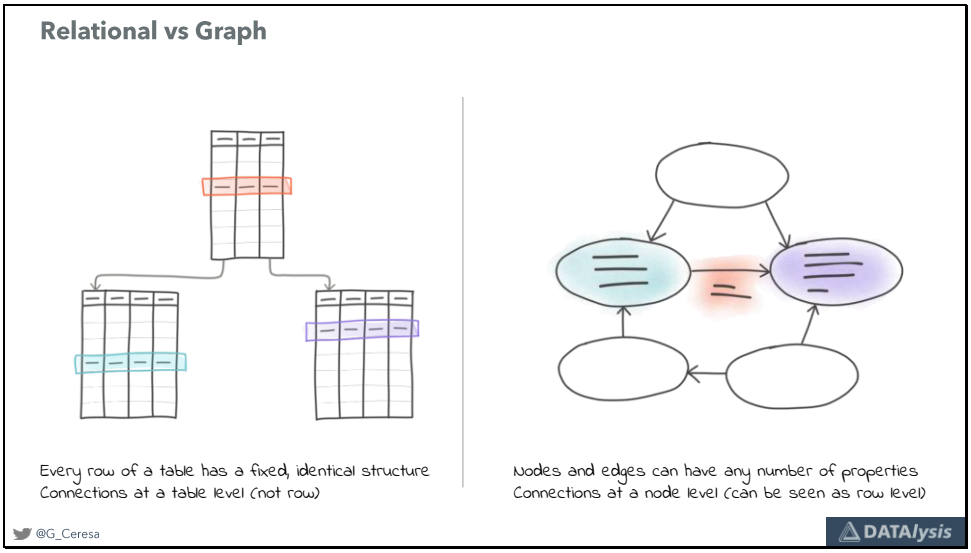
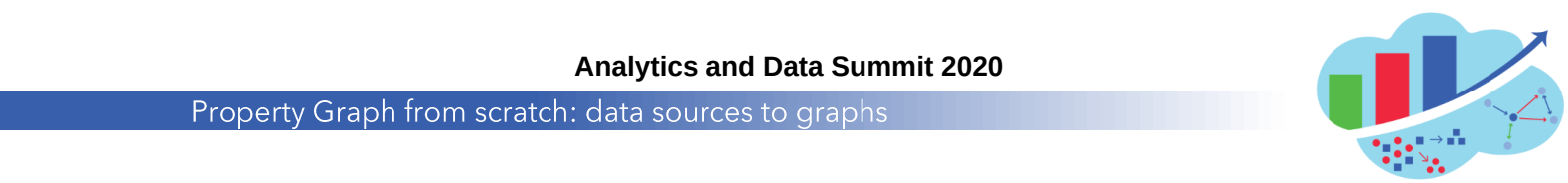


Every single row in those tables always has the exact same set of rows (except if you have a big blob or varchar column and store XML or Json inside, but let's not start talking dirty early in the morning).
The relation isn't at a row level but defined at the table level and all the rows must follow it.

In the graph every node has a different list of properties: one can have 3, one 4, no mandatory structure.
What is a table in the relational database can be an edge in a graph: a mapping table can be turned into an edge with the attributes to qualify it as properties (for example a customer buying products).



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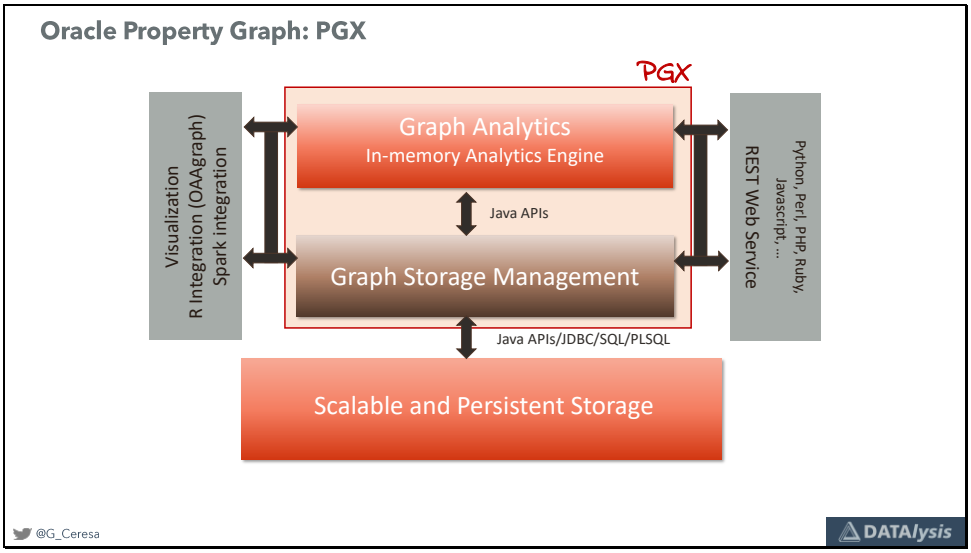
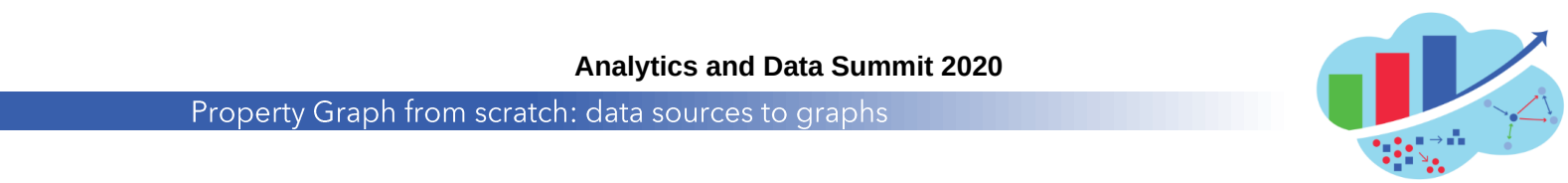


In Oracle the graph "engine", the brain, is called PGX. It's the acronym for Parallel Graph Analytics. PGX doesn't implement a full storage layer, it instead use existing options which could be an Oracle Database, an Oracle NoSQL database or HBase. Even a simple file in the filesystem.
PGX "speaks" REST: this allow to connect to it easily from almost any kind of tool or language.



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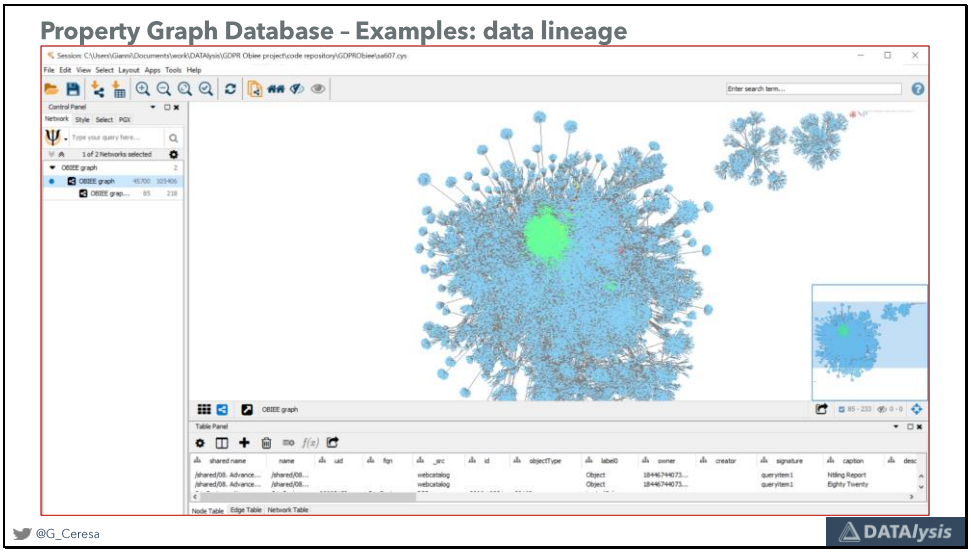

Examples of what a property graph can be used for is data lineage.
Imagine having an analytical platform like Oracle Analytics Cloud or Oracle Analytic Server (or the good old OBIEE). Some ETL processes and data source. All these elements have many mappings and connections between them. They can perfectly represented by a graph.

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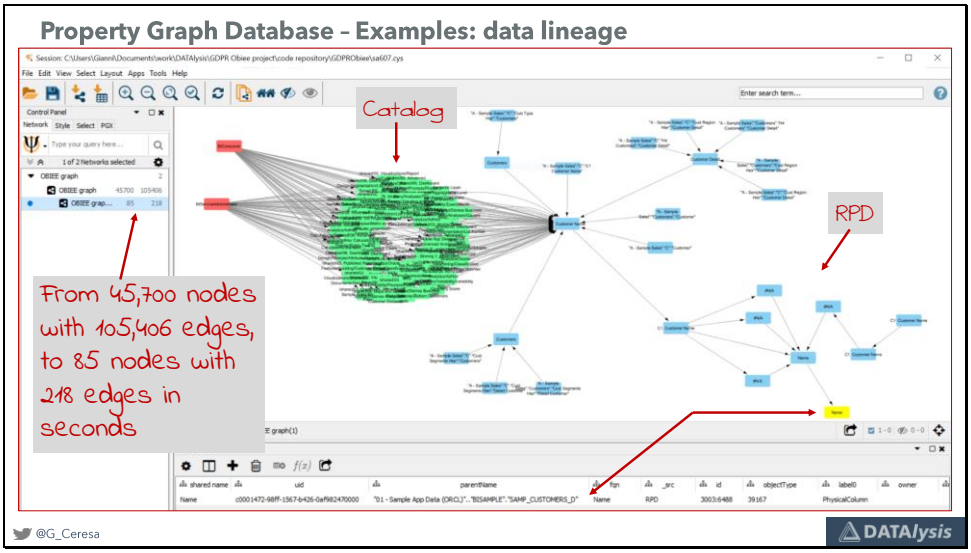
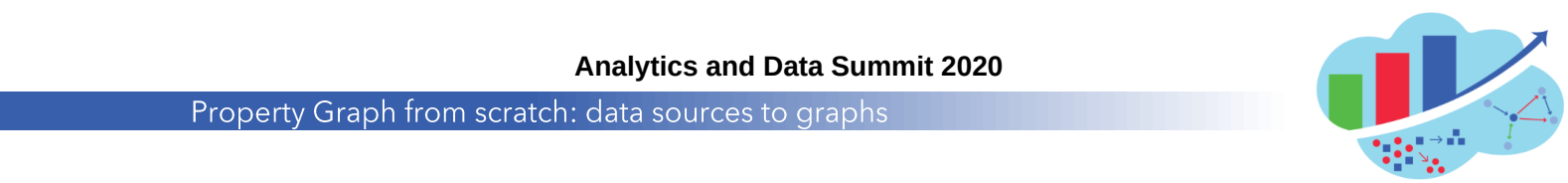


Thanks to the graph it's possible to easily perform impact analysis: what are all the elements I will have to fix if I decide to remove a given column from a physical source in my Oracle Analytics Cloud? The graph provides an answer in less than a second thanks to the in-memory processing.



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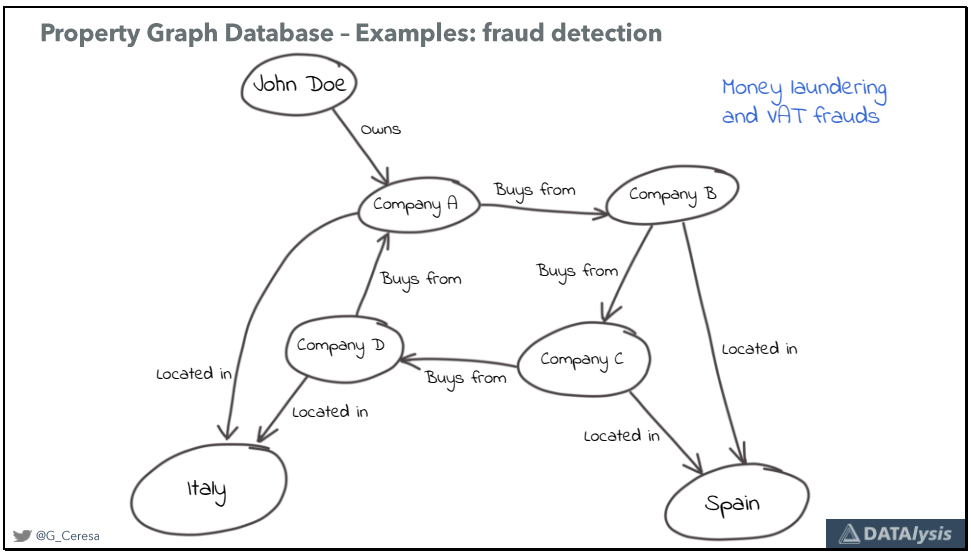

Another usage of graphs can be fraud detection: finding loops of money circulating and coming back at the origin.

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Property Graph Database – Examples: shortest path

Examples of graphs and graphs analytics can be seen when traveling from a location A to a location B :

Finding shortest path between 2 nodes of a graph

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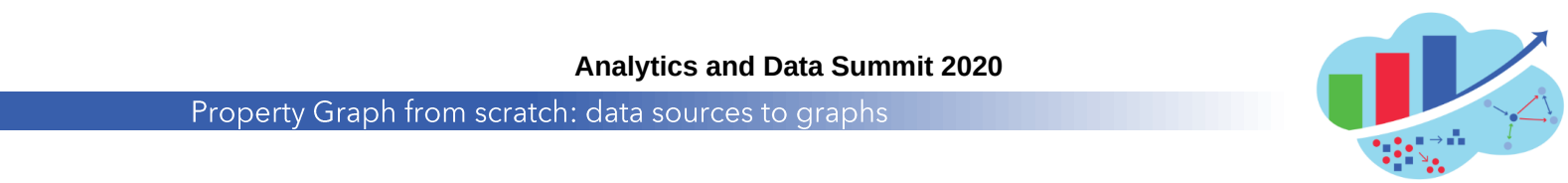
One of the simplest and most obvious usages is finding paths. Imagine at all the possible flights existing. How do you go from A to B in the fastest way? In the cheapest one? Etc.



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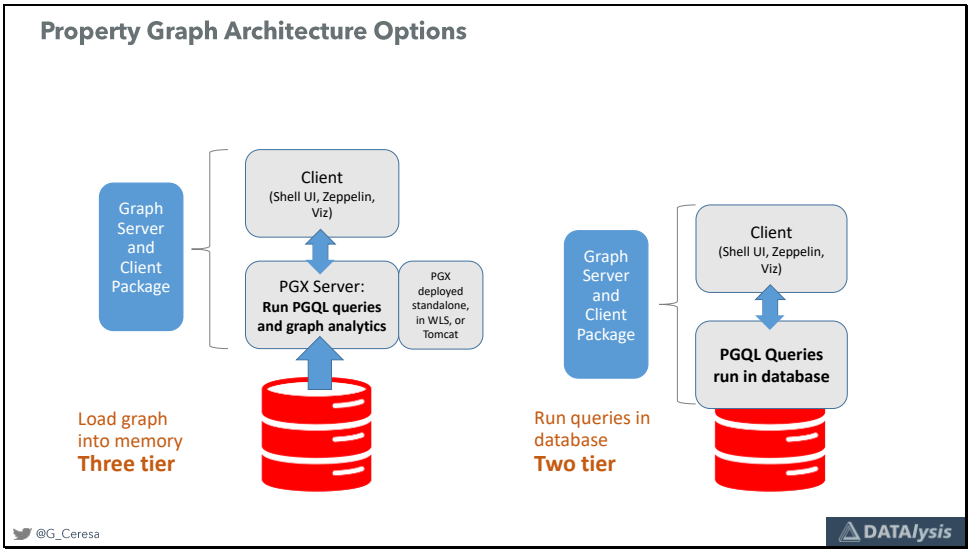
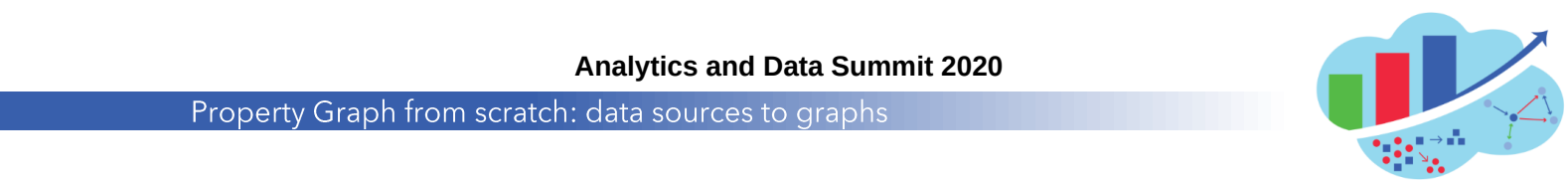


Oracle Property Graph can be used in 2 ways: the two tier approach which run graph queries directly on the Oracle database used for storing the graph. The graph query language, PGQL, is translated into standard SQL to provide the answer to the request.
The more classical approach, and the one giving access to the full power of Oracle property graph is by using PGX. A graph is loaded from the storage layer into PGX. Clients connect to PGX and perform PGQL queries or execute algorithms for their analysis. PGX can be executed as standalone process or by deploying it in an application server.



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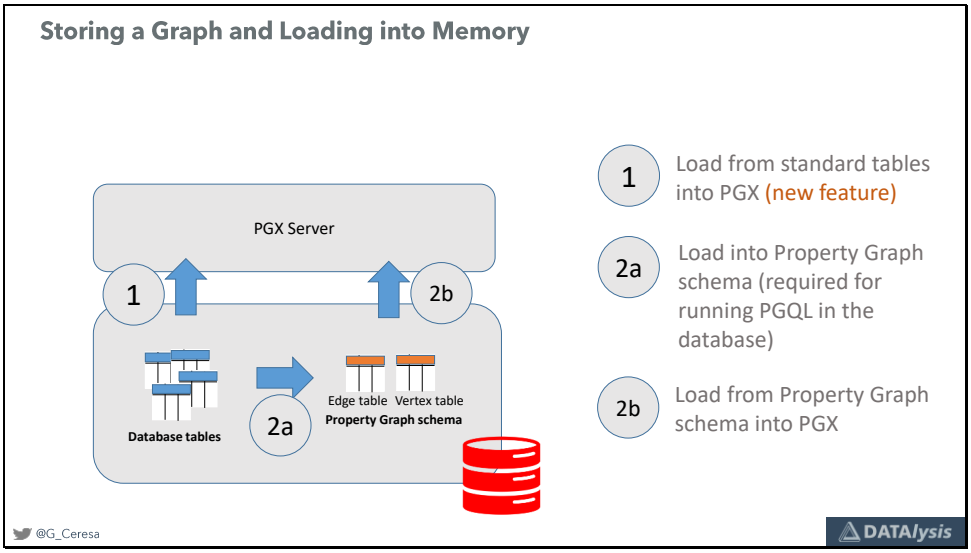

When loading a graph into PGX from a relational database, two different ways are not possible with the release of Graph server 20.1.0.
The "direct" (1) way is providing to PGX a configuration defining all the objects to load from database objects directly, defining what nodes and edges are, the various properties etc.
The "classical" (2) way of loading a graph is a 2-step activity: first a graph schema is created in the database. This schema is actually 5 tables with a fixed structure and indexes and partitioning already defined. You will load into these tables the content of the graph (2a). After you can tell PGX to load the graph (2b) by simply providing the graph name, database connection parameters and the list of properties you want to load for both nodes and edges (so you load only what you really need for a faster load time and a minimal memory usage).
This lab with follow the "classical" way, performing both 2a and 2b.

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Test connectivity & environments for Labs
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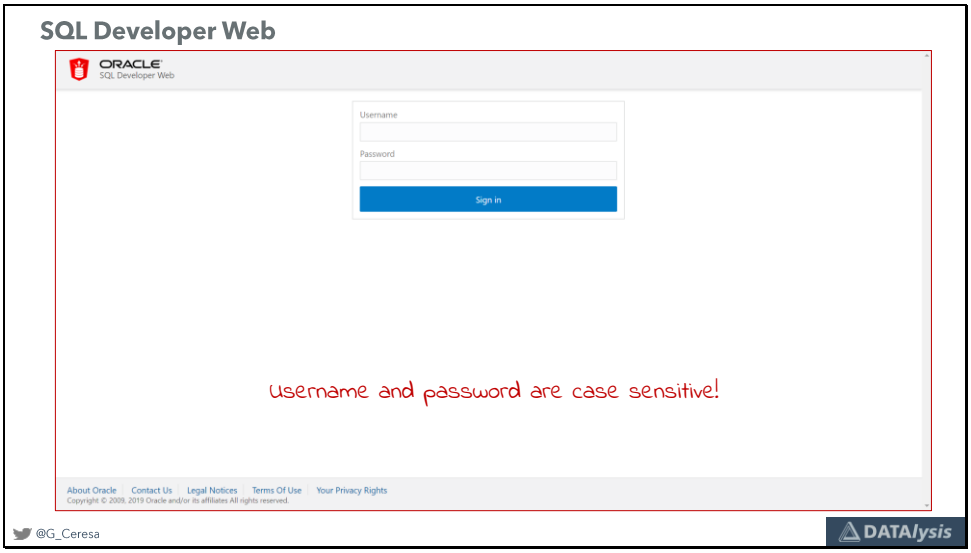
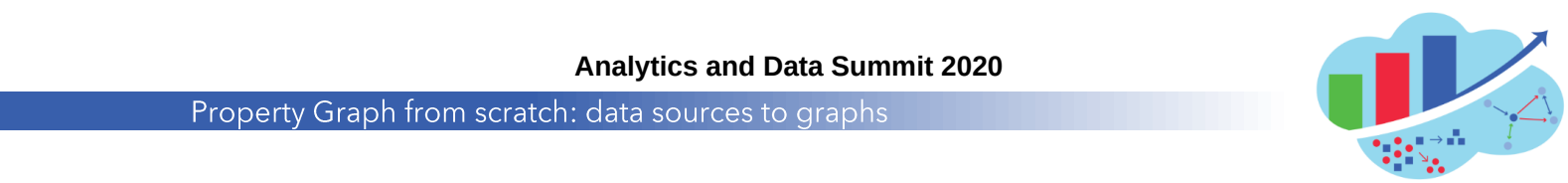


The lab uses an Autonomous Data warehouse in the cloud to store the graph. To connect SQL Developer web is used. It is available by default in the Autonomous Data warehouse cloud instance.
You can also use SQL Developer or any other tool able to perform SQL operations in the database.



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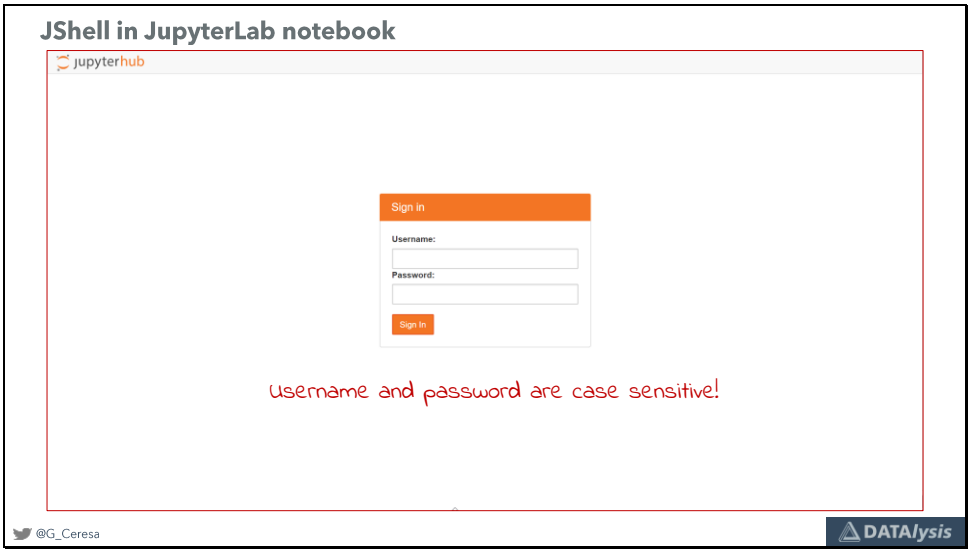

For the part related to PGX itself a JupyterLab notebook is used to provide a more friendly interface on top of the JShell PGX client. If you download the Graph client you have the JShell command line interface available directly (requires Java 11+). The notebook doesn't provide extra features for PGX itself, but has the advantage to allow to add comments in markdown etc.

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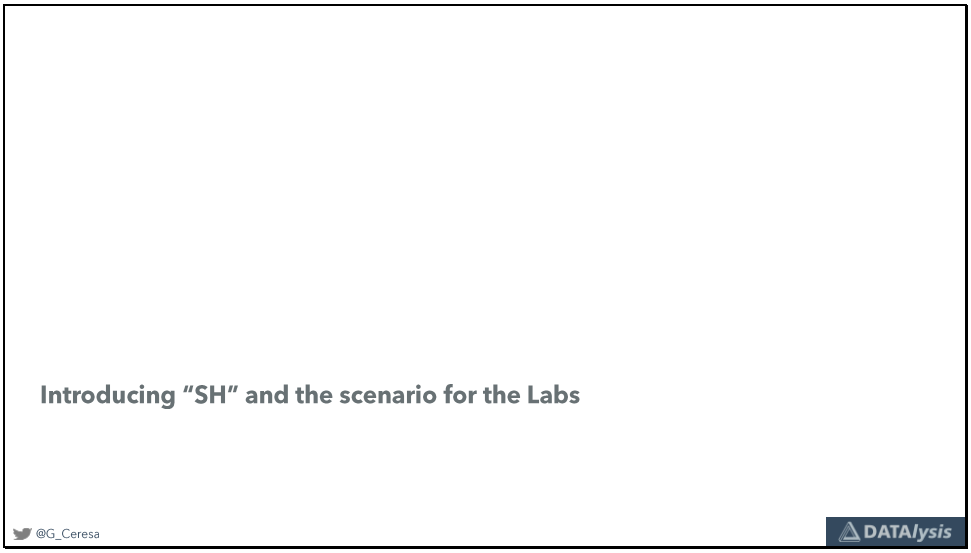
Introducing "SH" and the scenario for the Labs
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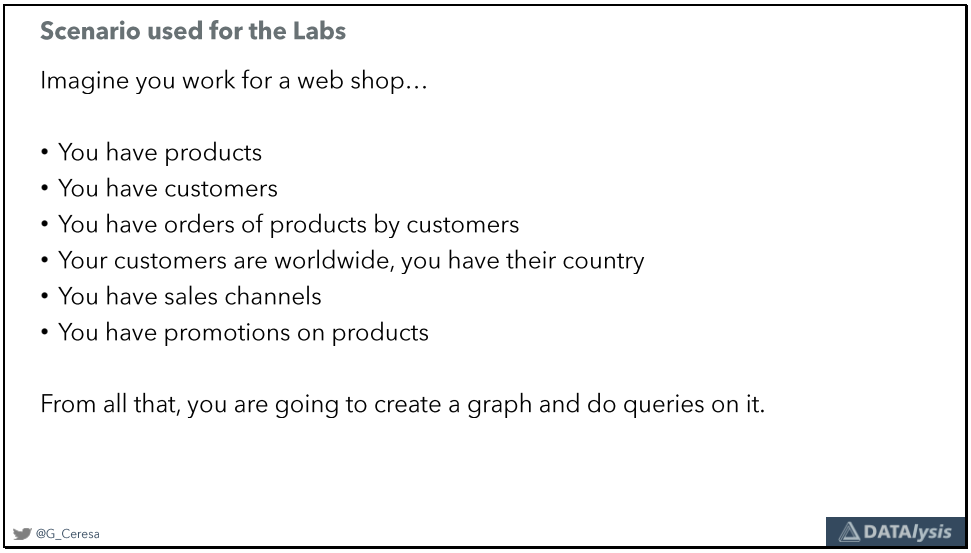

The lab scenario is a simple e-shop commerce activity.

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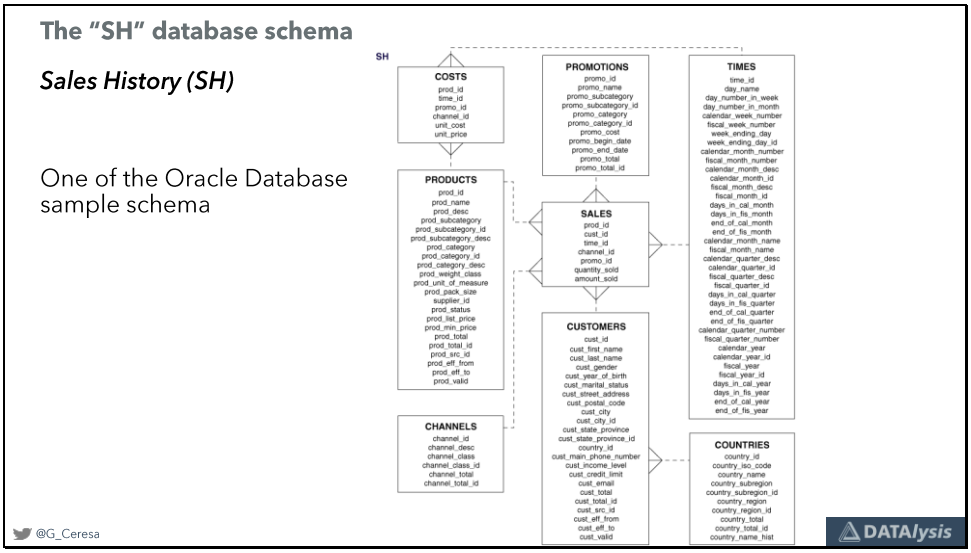

"SH" is one of the historical database schema examples. It is available all the time in Oracle Autonomous Data warehouse without the need to install or enable it.

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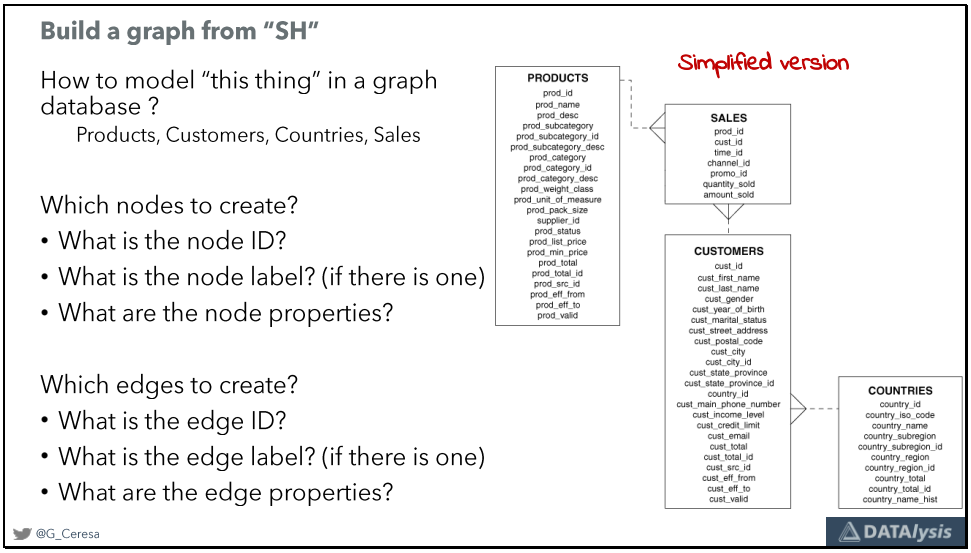

To build a graph the challenge, like any other database or solution, is to find the right model.

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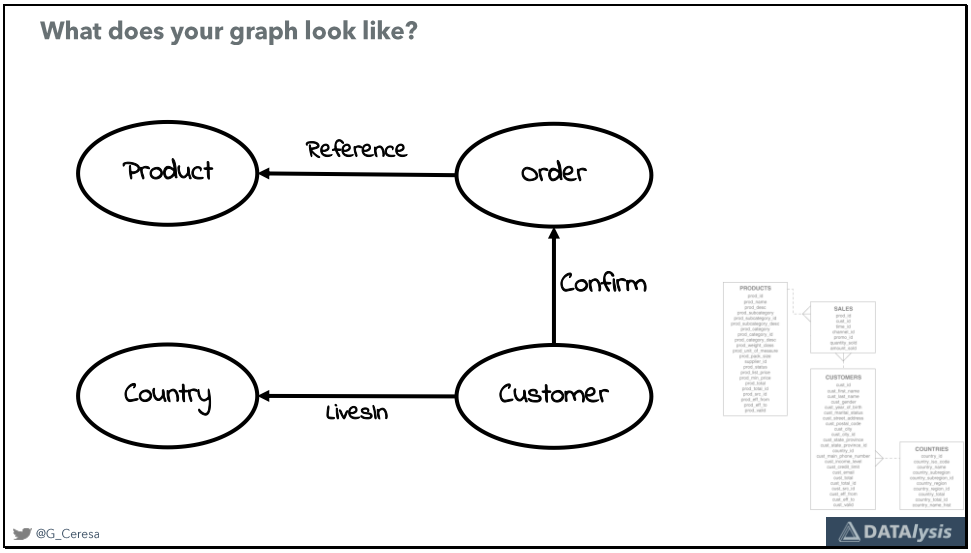

4 tables could be turned into a graph with a node for each row of each table.

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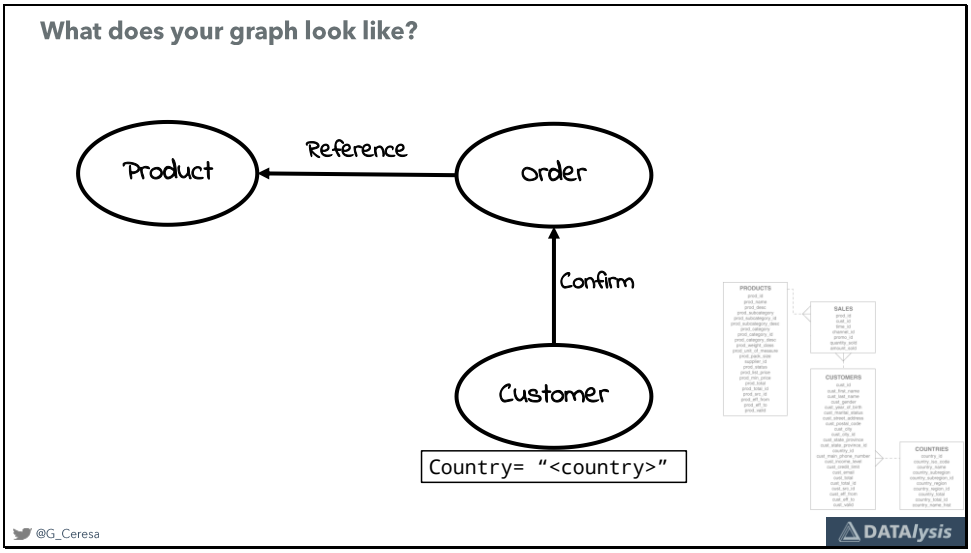

But the content of one of the tables could also be loaded as a property of another node.

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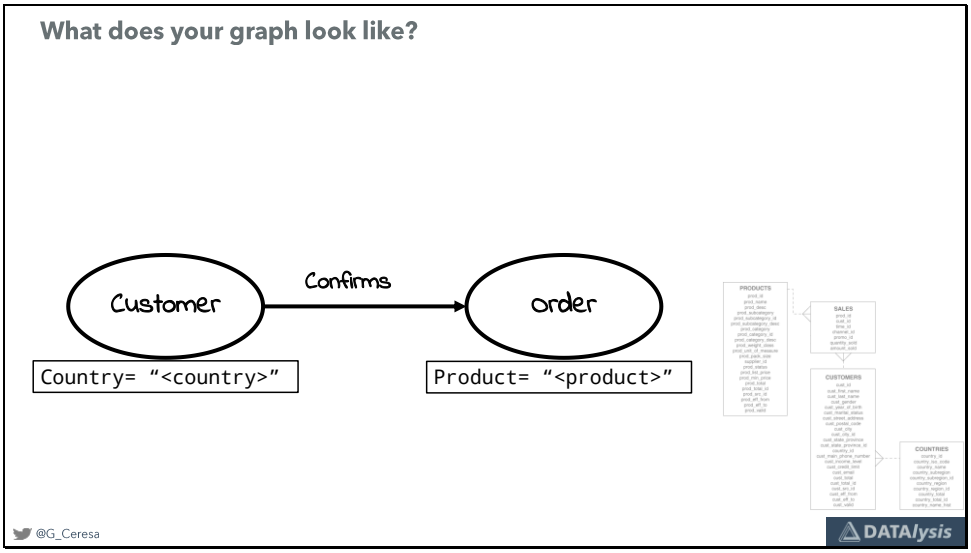

And the logic can be applied to reduce the graph even more.

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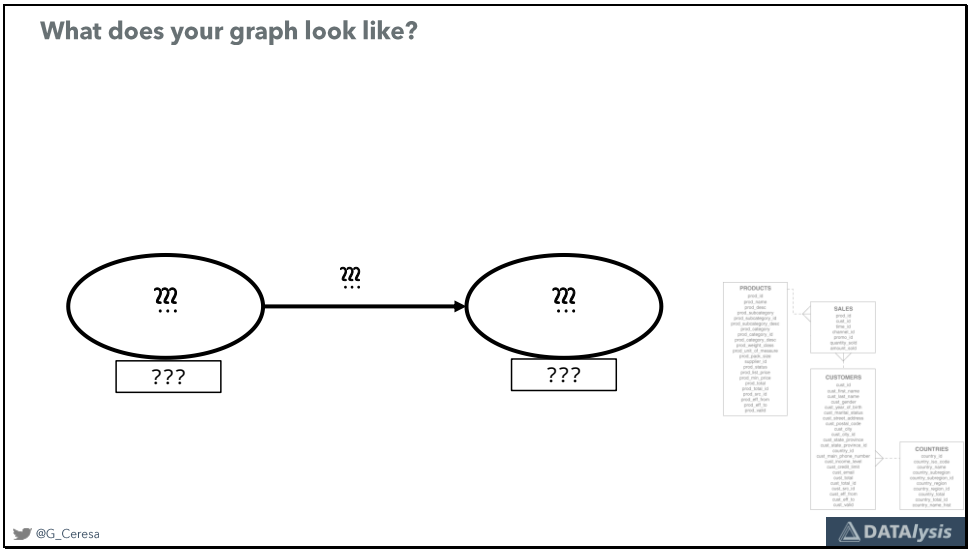

All these models aren't wrong. Technically they are graph still. The question is: are they going to allow you to perform the analysis you need?

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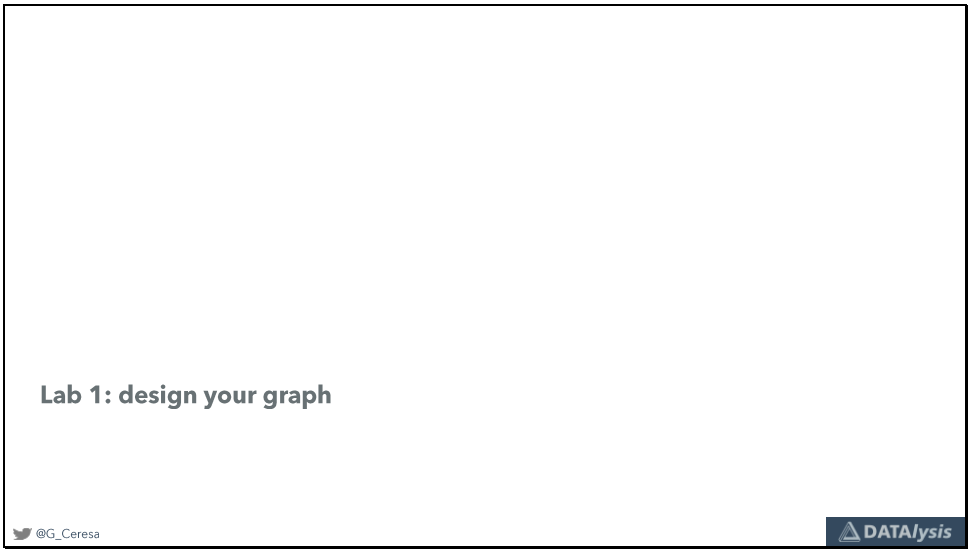
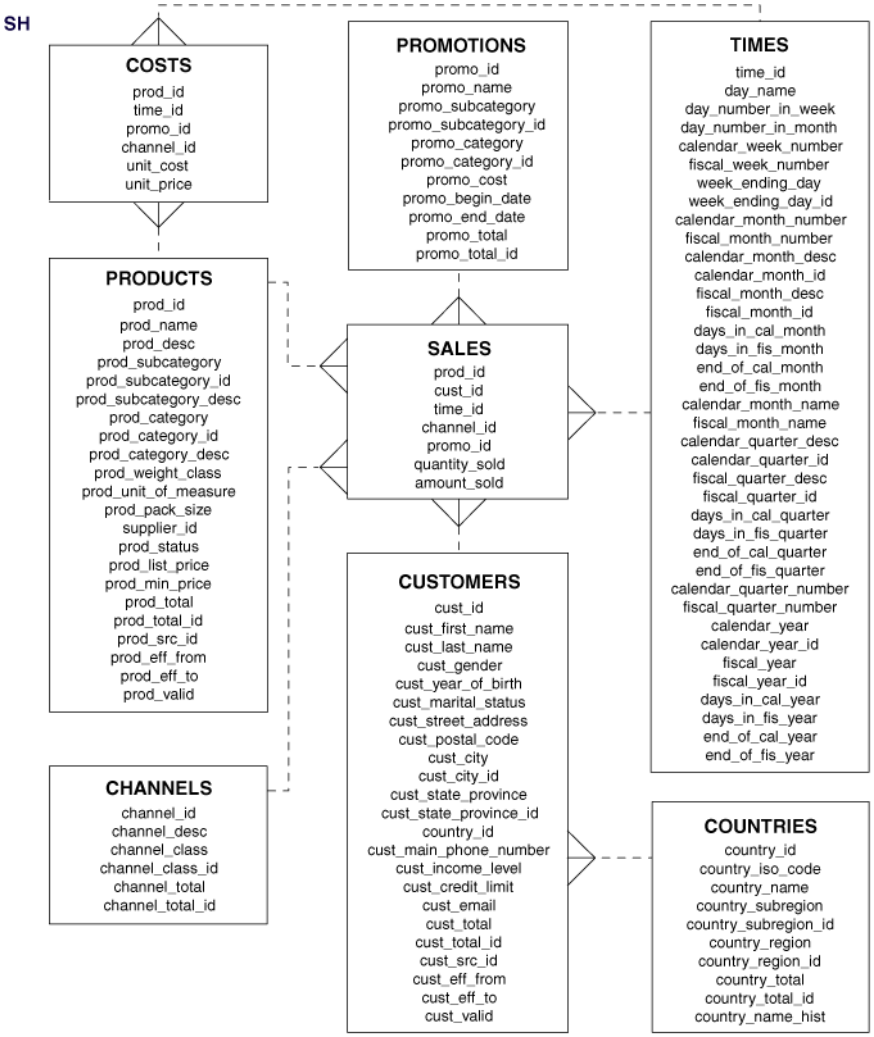


Lab 1: Design your graph

> **Target**
>
> In this Lab you will design possible graph structures derived from the scenario and the available sources.

The context of this lab is a simple sales activity, with customers buying products. It's one of the historical sample schemas you can have with any Oracle Database and it's also available by default in any Autonomous Database.

Oracle Sales History (SH) schema diagram



Focusing on a reduced model covering only the tables “PRODUCTS”, “SALES”, “CUSTOMER” and “COUNTRIES”, design on a piece of paper the possible structure of your graph in a generic way.

With a single node identified by its label and listing the properties keys. Add the edges connecting these nodes and identify the label and properties for the edges as well.

There isn’t a right or wrong model as long as you respect the basic rules and technical constraints of a property graph.
But a model will be easier to query than another.

The expected usage drives the choice of the model, like when you design a data warehouse or any other relational database.

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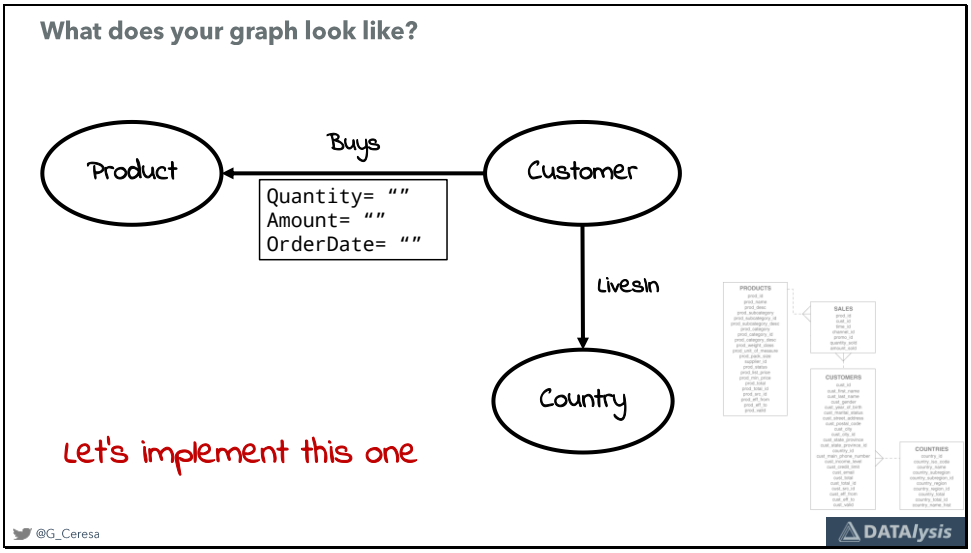

A model with seem well balanced for most of the needs is to load the "order lines" as edges, connecting the customer and various products composing each order.

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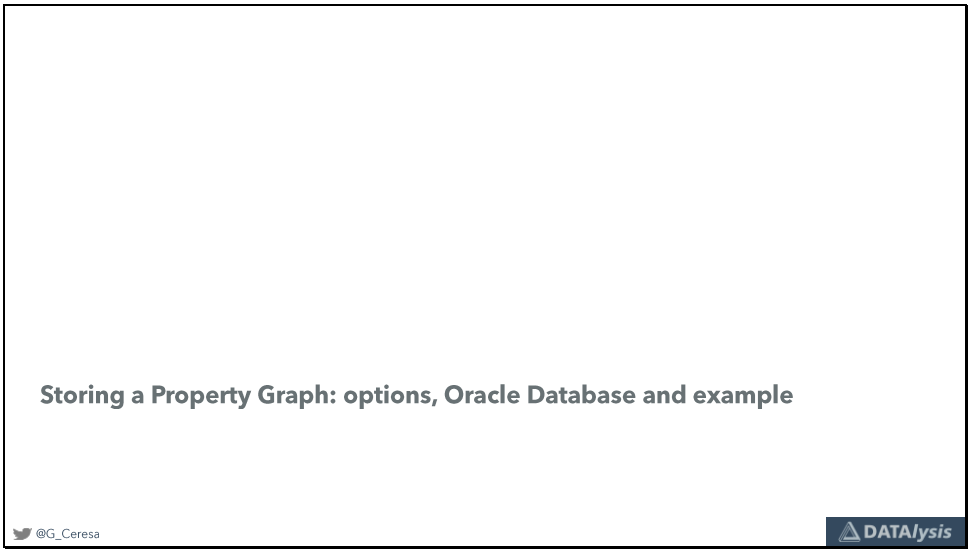
Storing a Property Graph: options, Oracle Database and example
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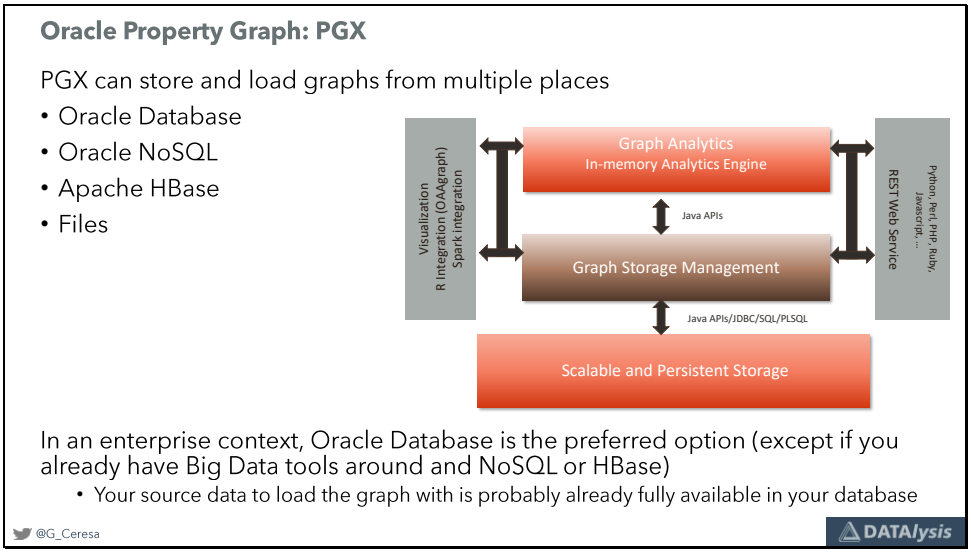

In an Enterprise environment we can exclude the storage in files, this one can work for sandboxing and testing, but not for a real usage.
Companies generally always have most of their data into a database, therefore it makes sense to store the graph there. This also allow to be compliant with security or auditing rules as these processed would already be known.

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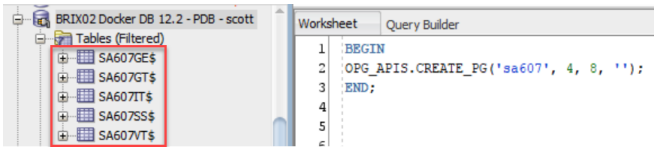
Oracle Database – Create a new graph

What you need:

- Oracle Database 12c R2 or newer (including Autonomous)
- Extended Data Types (to have varchar of more than 4'000)

```
BEGIN
  OPG_APIS.CREATE_PG('name_of_your_graph');
END;
```



GE$: edges of the graph
VT$: vertices of the graph
GT$: graph skeleton
IT$: text index metadata
SS$: graph snapshots

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To create a graph in the database you have to call a method. The mandatory parameter is the graph name, others are available. Reference to the documentation for all the details.
The result is 5 tables named like the graph name plus a suffix.

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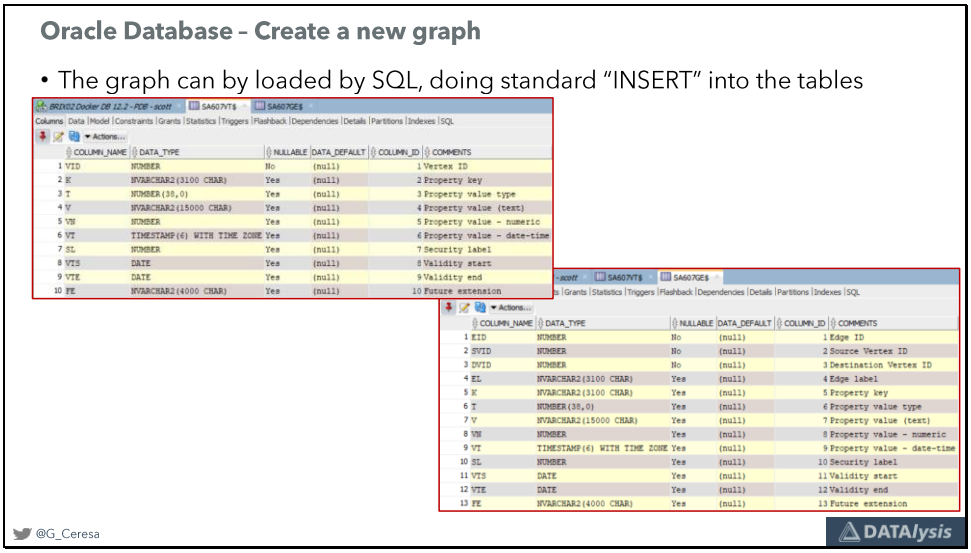
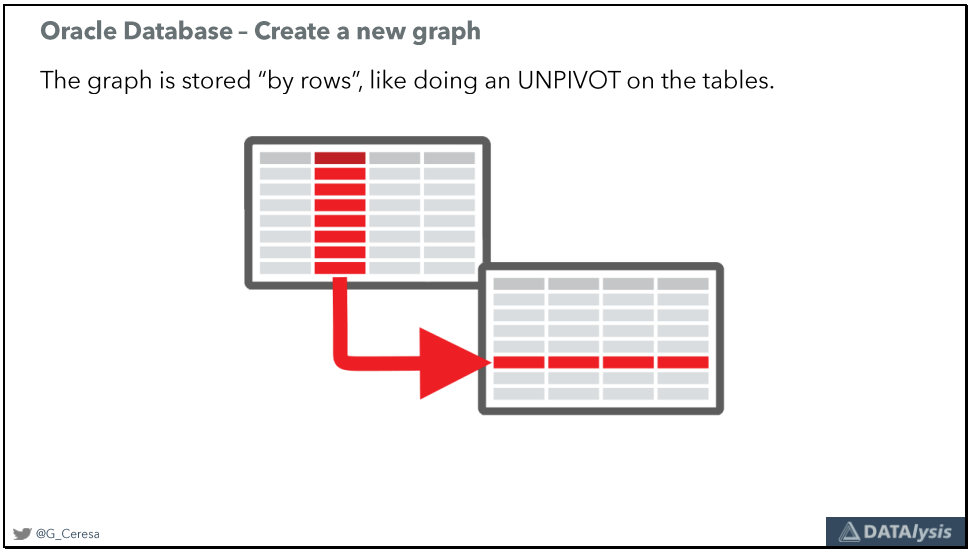


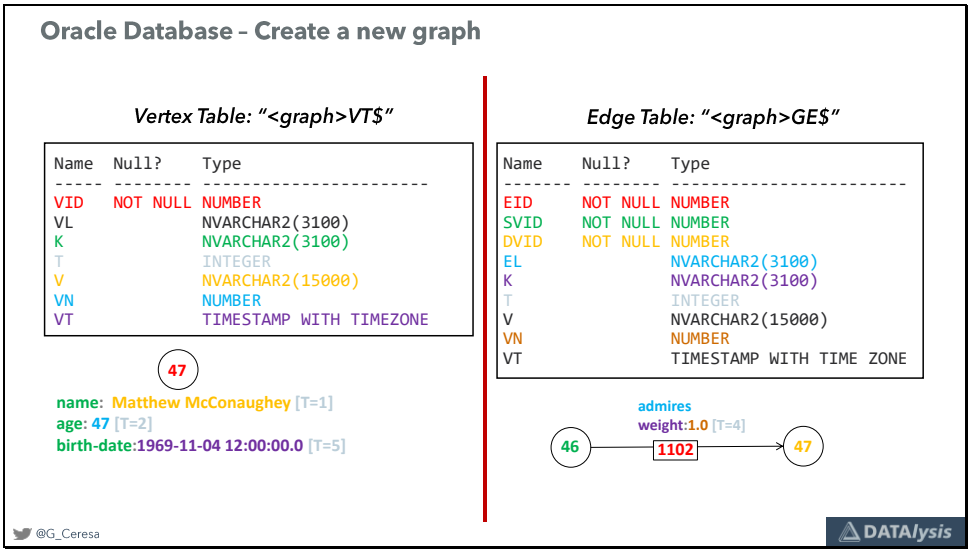
The structure of the tables for vertices and edges is fairly similar. Content is stored by row, this means that every property will be a row, and the VID would be repeated for the nodes. For the edges it's the same thing but the 4 columns EID, SVID, DVID and EL would be repeated to store the properties on edges by row.

Slide 36



The sources used to populate the graph are generally storing information by columns (the various columns of a table). To load this into a graph an "UNPIVOT" operation must be performed turning columns into rows.

Slide 37



A visual representation, with matching colours, of what information is stored in which column of the tables.

Slide 38

Oracle Database – Create a new graph

Data Types:

- All numeric properties go in VN
- Date/time properties go in VT
- All others go in V
- Booleans are encoded as "Y" / "N"

NOTE: All numeric and date properties are also stored in V in printable format (to enable text indexing)

ID	Data type	Column
1	String	V
2	Integer	VN
3	Float	VN
4	Double	VN
5	Date	VT
6	Boolean	V
7	Long	VN
8	Short	VN
9	Byte	VN
10	Char	V
101	Serializable	V

@G_Ceresa DATAlysis

The properties can have various types. To keep track of this information the column T is used, and the columns VN and VT with the appropriate data type exists.

Slide 39

Oracle Database – Create a new graph

- These tables are just "normal" tables, queries can be done …
- Support some graph algorithms, the doc list all the supported methods
  https://docs.oracle.com/en/database/oracle/oracle-database/18/spgdg/OPG_APIS-reference.html

Worksheet | Query Builder

```
1
2  select 'Graph has ' || count(distinct eid) || ' edges' from sa607ge$
3  union all
4  select 'Graph has ' || count(distinct vid) || ' vertices' from sa607vt$;
5
6
```

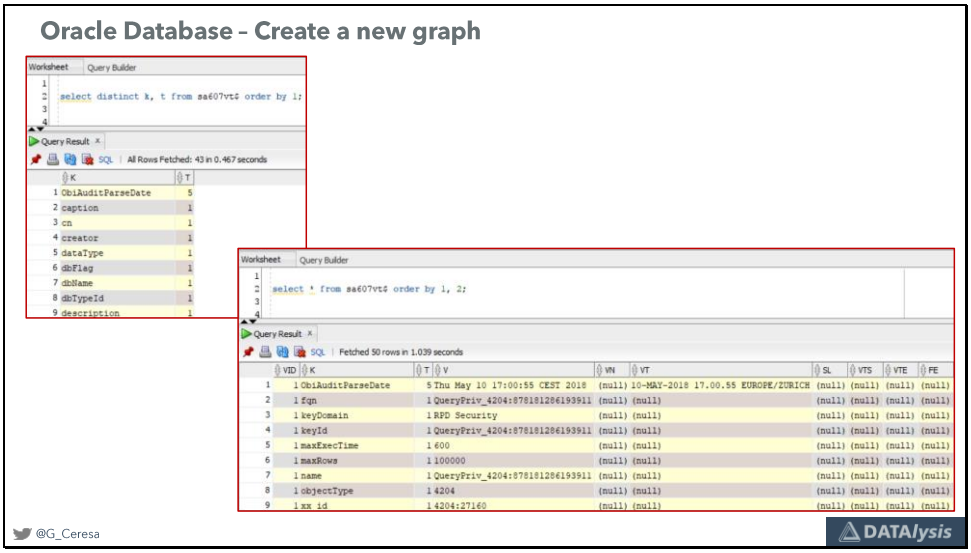
Query Result | SQL | All Rows Fetched: 2 in 0.169 seconds

	'GRAPHHAS'||COUNT(DISTINCTEID)||'EDGES'
1	Graph has 105500 edges
2	Graph has 48155 vertices

@G_Ceresa DATAlysis

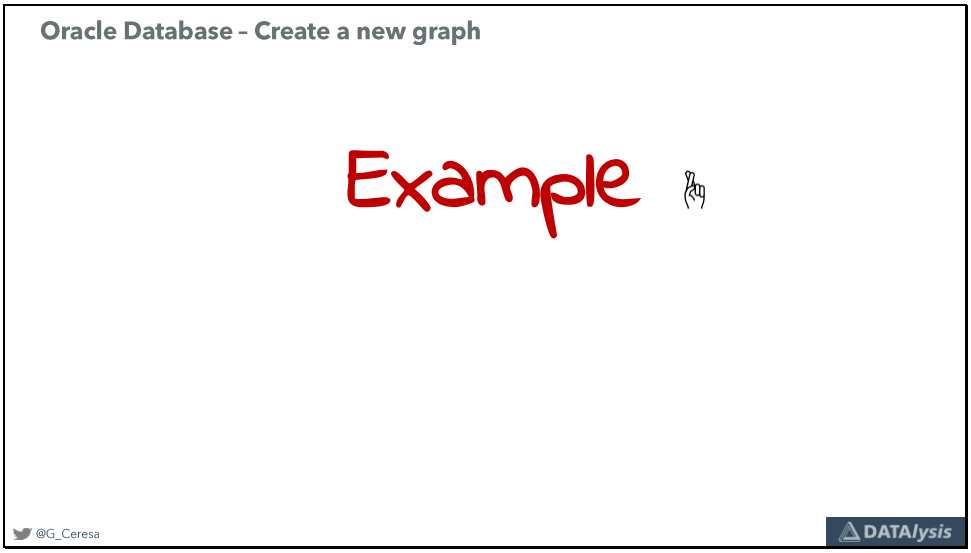
Once a graph is loaded in the database (which is the storage layer in this case), normal queries can be performed as it's "just" tables in a database.

Slide 40

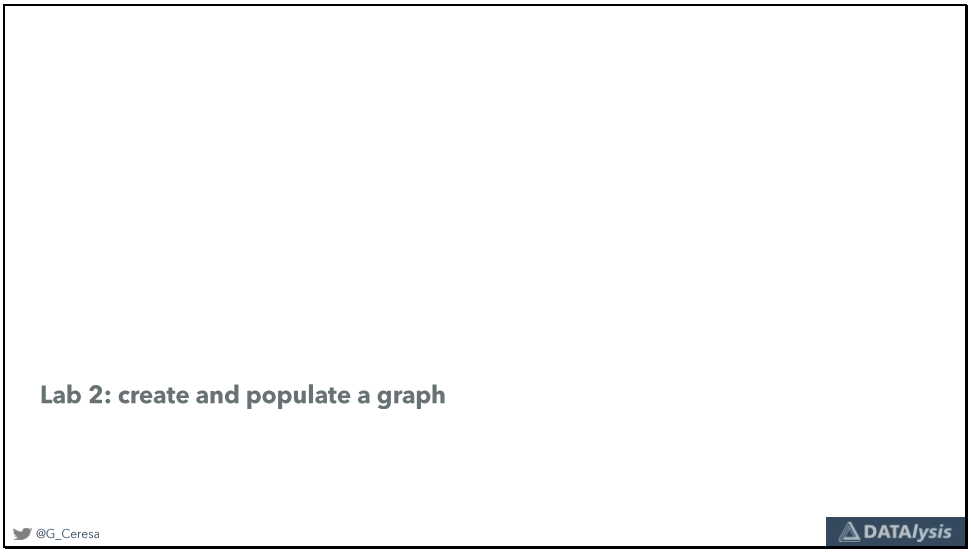


Clearly queries can be fairly simple or get quite complex if you try to perform real graph queries writing SQL yourself by hand.

Slide 41


Oracle Database – Create a new graph
Example
@G_Ceresa
DATAlysis

Slide 42

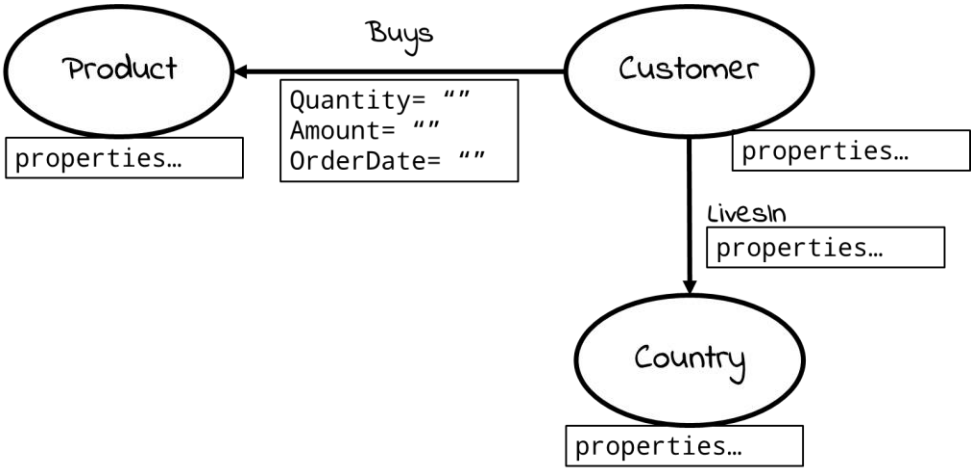


Lab 2: Create and populate a graph

> **Target**
>
> After this lab you will have in the Oracle Autonomous Datawarehouse relational database a property graph stored in the graph schema and with all the nodes, edges and properties populated with data.

For this Lab you will work only in SQL Developer Web, using the URL and credentials provided.

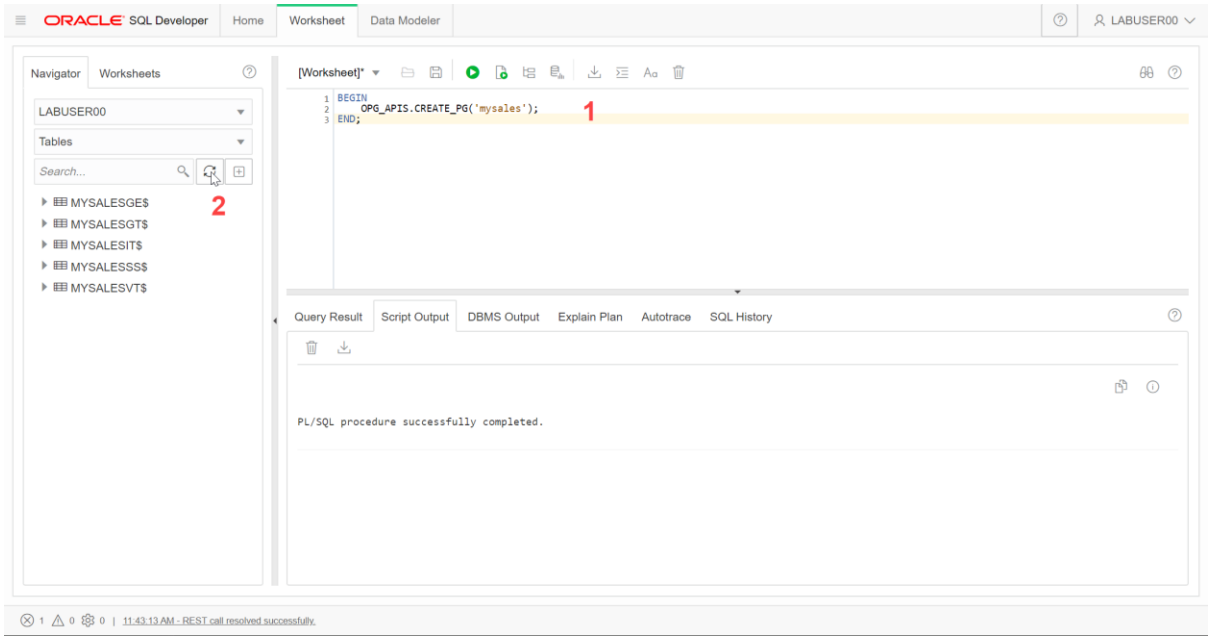
The graph you are going to create has the following structure.



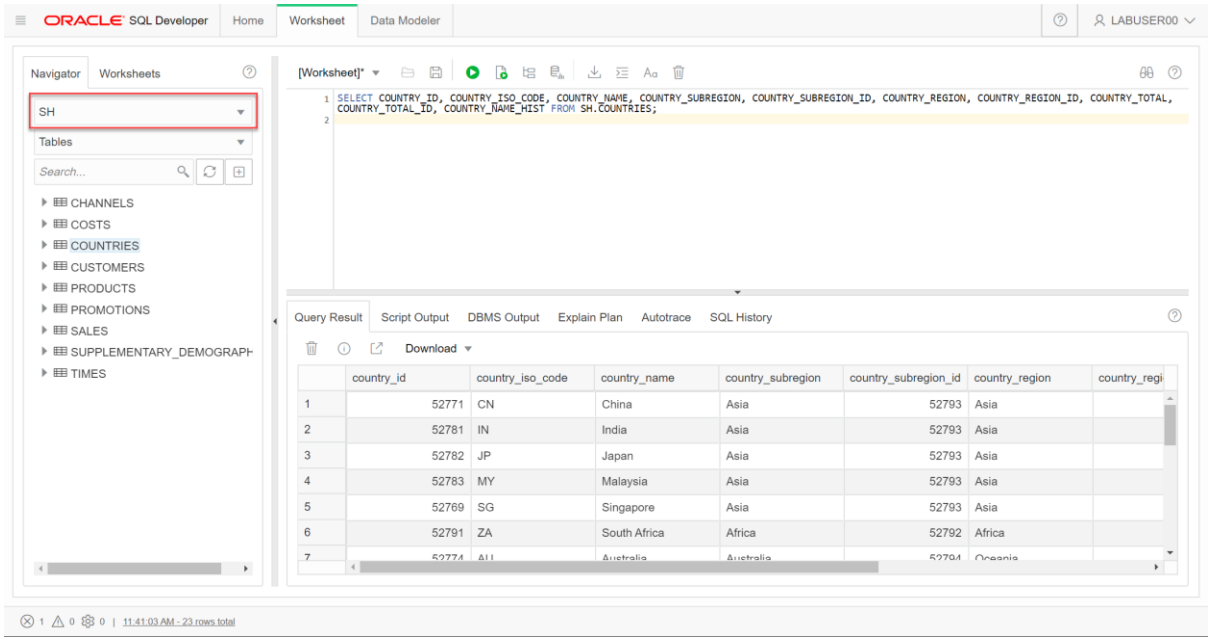
1) To create the tables with the fixed structures to store the graph execute the following code.

```
BEGIN
      OPG_APIS.CREATE_PG('mysales');
END;
```

Refreshing the list of tables in your own schema you will see the newly created tables for the graph.



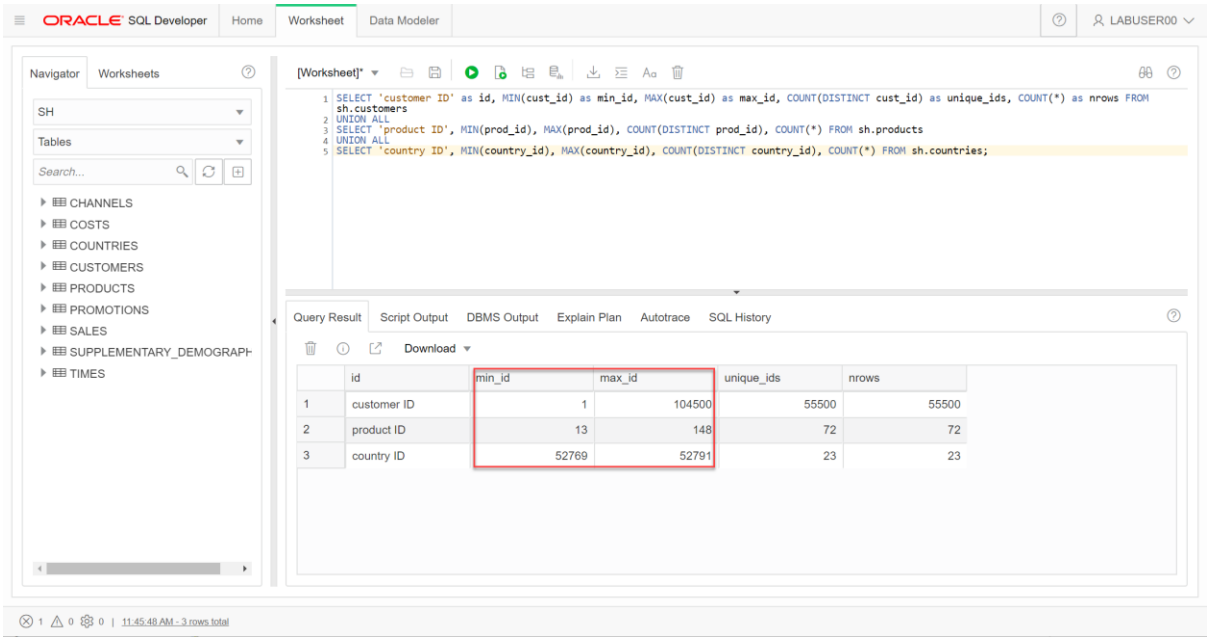
2) Inspect the source data you are going to use to populate your graph by switching to the SH schema.



3) Verify if the primary keys of the existing tables can be used as IDs for the nodes. Node's IDs are unique across the whole graph, while a table primary key is generally unique only in the table itself.

```
SELECT 'customer ID' as id, MIN(cust_id) as min_id, MAX(cust_id) as
max_id, COUNT(DISTINCT cust_id) as unique_ids, COUNT(*) as nrows
FROM sh.customers
UNION ALL
SELECT 'product ID', MIN(prod_id), MAX(prod_id), COUNT(DISTINCT
prod_id), COUNT(*) FROM sh.products
UNION ALL
SELECT 'country ID', MIN(country_id), MAX(country_id),
COUNT(DISTINCT country_id), COUNT(*) FROM sh.countries;
```

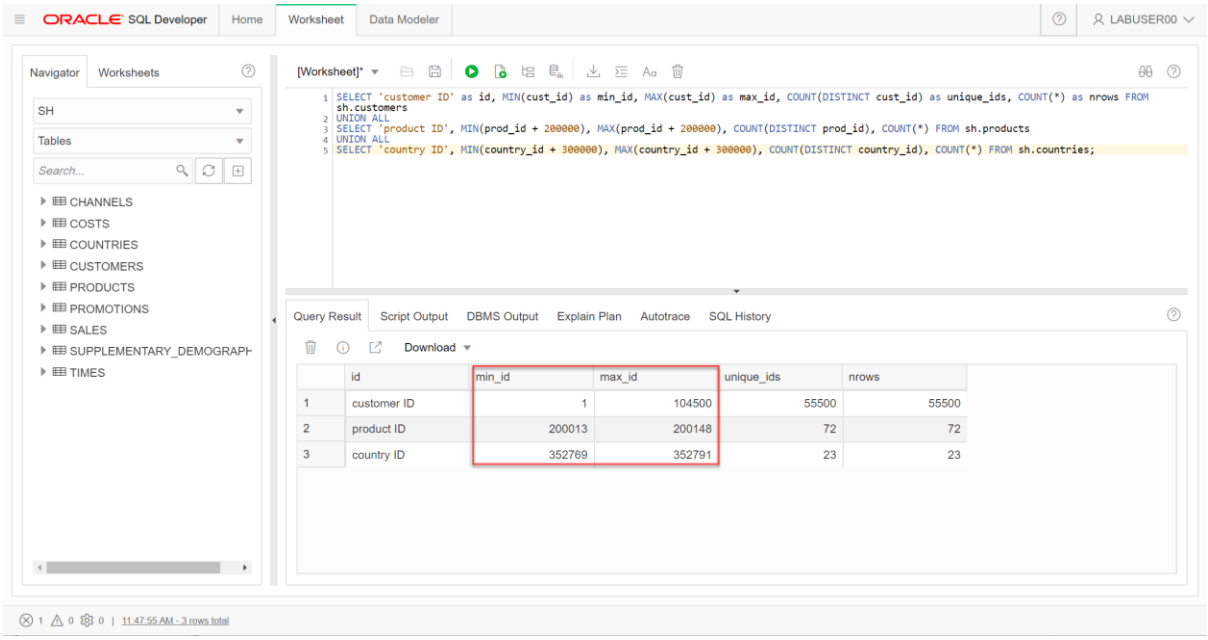
The IDs of the 3 tables overlaps, they can't be used as IDs for nodes directly.



4) One possible workaround for this problem is making the IDs unique adding an offset value by table.

```
SELECT 'customer ID' as id, MIN(cust_id) as min_id, MAX(cust_id) as
max_id, COUNT(DISTINCT cust_id) as unique_ids, COUNT(*) as nrows
FROM sh.customers
UNION ALL
SELECT 'product ID', MIN(prod_id + 200000), MAX(prod_id + 200000),
COUNT(DISTINCT prod_id), COUNT(*) FROM sh.products
UNION ALL
SELECT 'country ID', MIN(country_id + 300000), MAX(country_id +
300000), COUNT(DISTINCT country_id), COUNT(*) FROM sh.countries;
```

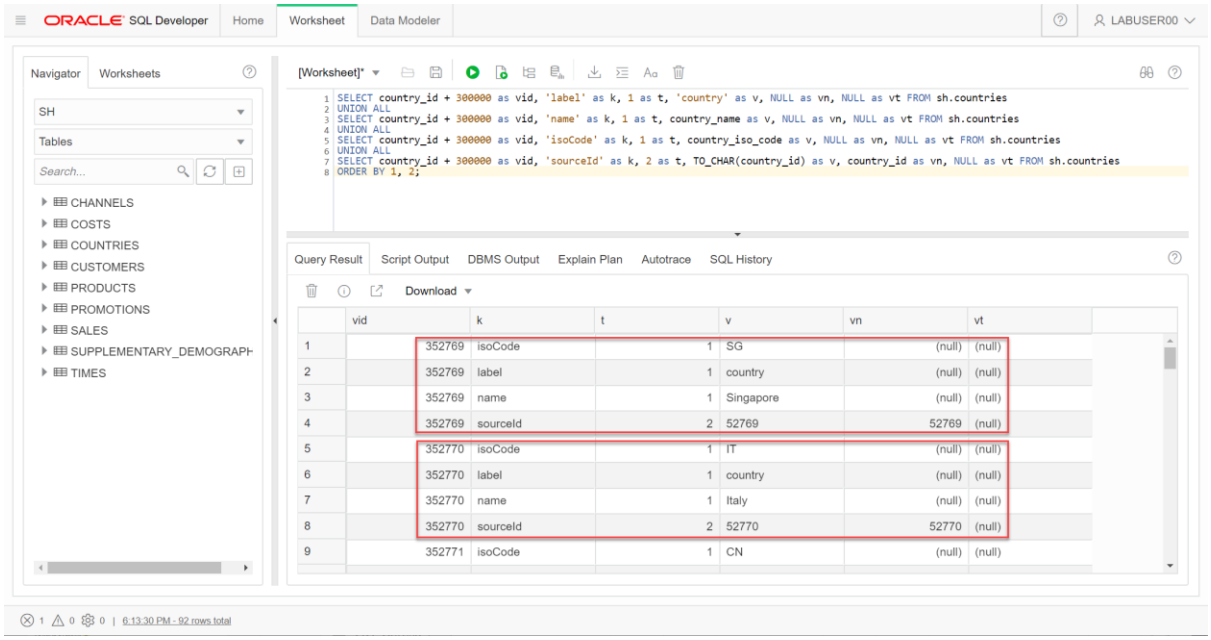
The IDs aren't overlapping anymore. This workaround is valid only during tests and must not be used in a real production environment as nothing prevent the IDs to keep growing and overlap again at some point.



5) Prepare the nodes representing the countries, performing the UNPIVOT to transform columns into rows and formatting the result to respect the graph rules. This is a validation step testing the query only.

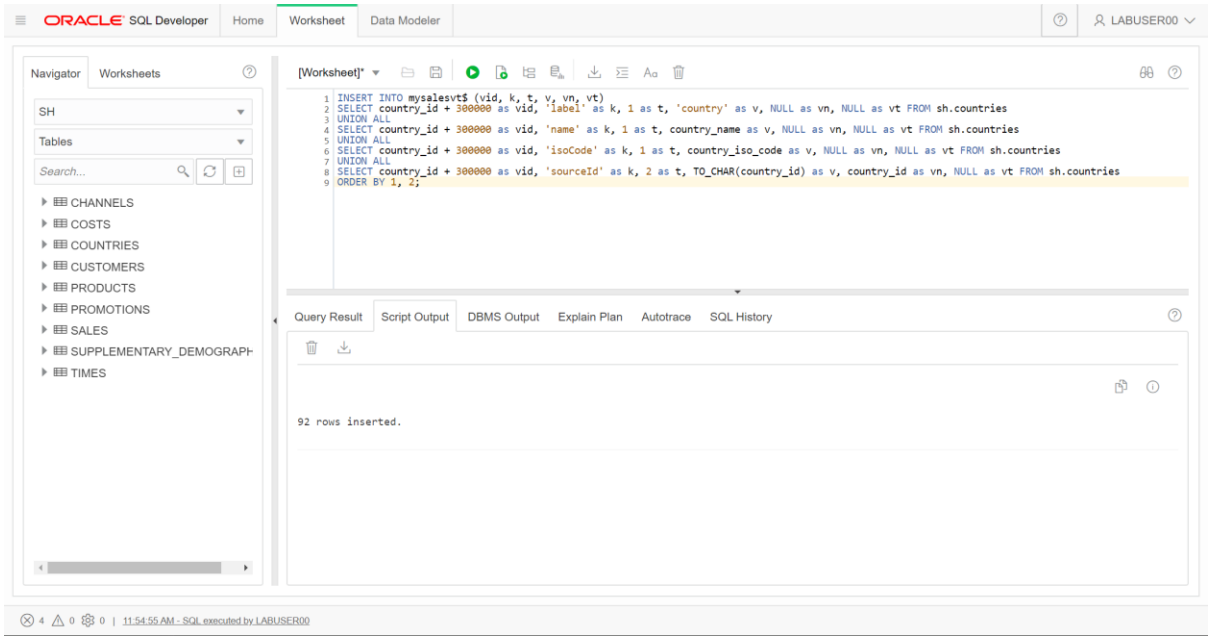
```
SELECT country_id + 300000 as vid, 'label' as k, 1 as t, 'country'
as v, NULL as vn, NULL as vt FROM sh.countries
UNION ALL
SELECT country_id + 300000 as vid, 'name' as k, 1 as t, country_name
as v, NULL as vn, NULL as vt FROM sh.countries
UNION ALL
SELECT country_id + 300000 as vid, 'isoCode' as k, 1 as t,
country_iso_code as v, NULL as vn, NULL as vt FROM sh.countries
UNION ALL
SELECT country_id + 300000 as vid, 'sourceId' as k, 2 as t,
TO_CHAR(country_id) as v, country_id as vn, NULL as vt FROM
sh.countries
ORDER BY 1, 2;
```

Don't forget the offset added to the IDs, the "ORDER BY" is there to help highlighting the fact that a single node has multiple rows repeating the ID.



6) Insert the rows representing the countries nodes in the table.

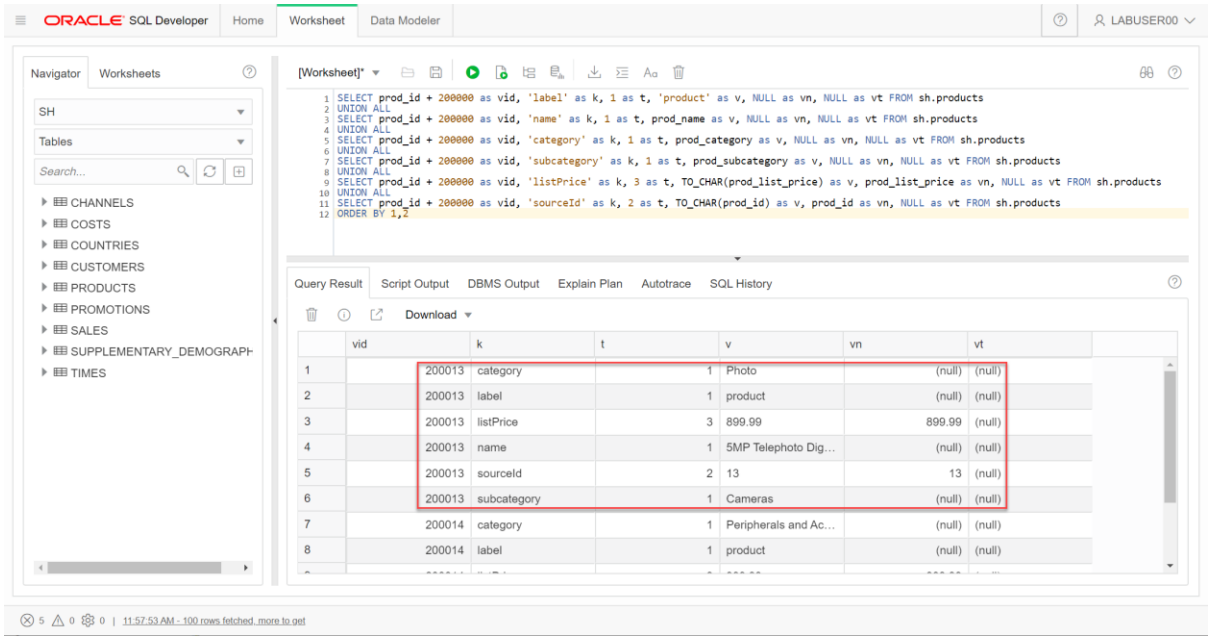
```
INSERT INTO mysalesvt$ (vid, k, t, v, vn, vt)
SELECT country_id + 300000 as vid, 'label' as k, 1 as t, 'country'
as v, NULL as vn, NULL as vt FROM sh.countries
UNION ALL
SELECT country_id + 300000 as vid, 'name' as k, 1 as t, country_name
as v, NULL as vn, NULL as vt FROM sh.countries
UNION ALL
SELECT country_id + 300000 as vid, 'isoCode' as k, 1 as t,
country_iso_code as v, NULL as vn, NULL as vt FROM sh.countries
UNION ALL
SELECT country_id + 300000 as vid, 'sourceId' as k, 2 as t,
TO_CHAR(country_id) as v, country_id as vn, NULL as vt FROM
sh.countries
ORDER BY 1, 2;
```



7) Prepare the nodes representing the products, performing the UNPIVOT to transform columns into rows and formatting the result to respect the graph rules. This is a validation step testing the query only.

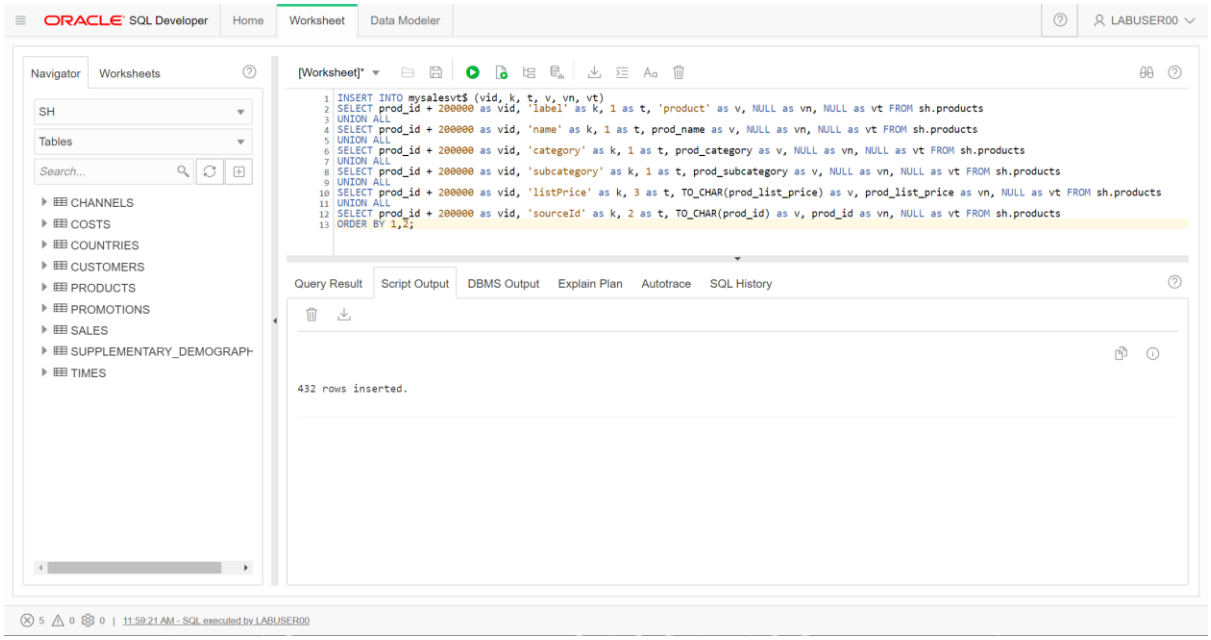
```
SELECT prod_id + 200000 as vid, 'label' as k, 1 as t, 'product' as
v, NULL as vn, NULL as vt FROM sh.products
UNION ALL
SELECT prod_id + 200000 as vid, 'name' as k, 1 as t, prod_name as v,
NULL as vn, NULL as vt FROM sh.products
UNION ALL
SELECT prod_id + 200000 as vid, 'category' as k, 1 as t,
prod_category as v, NULL as vn, NULL as vt FROM sh.products
UNION ALL
SELECT prod_id + 200000 as vid, 'subcategory' as k, 1 as t,
prod_subcategory as v, NULL as vn, NULL as vt FROM sh.products
UNION ALL
SELECT prod_id + 200000 as vid, 'listPrice' as k, 3 as t,
TO_CHAR(prod_list_price) as v, prod_list_price as vn, NULL as vt
FROM sh.products
UNION ALL
SELECT prod_id + 200000 as vid, 'sourceId' as k, 2 as t,
TO_CHAR(prod_id) as v, prod_id as vn, NULL as vt FROM sh.products
ORDER BY 1,2;
```

Don't forget the offset added to the IDs, the "ORDER BY" is there to help highlighting the fact that a single node has multiple rows repeating the ID.



8) Insert the rows representing the products nodes in the table.

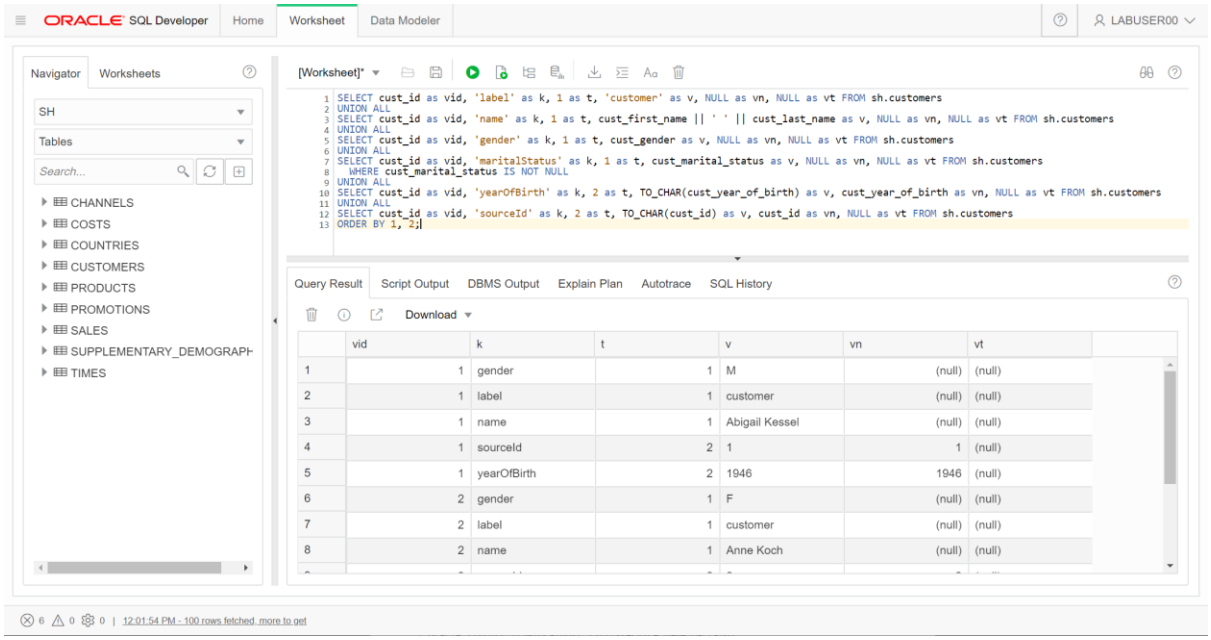
```
INSERT INTO mysalesvt$ (vid, k, t, v, vn, vt)
SELECT prod_id + 200000 as vid, 'label' as k, 1 as t, 'product' as
v, NULL as vn, NULL as vt FROM sh.products
UNION ALL
SELECT prod_id + 200000 as vid, 'name' as k, 1 as t, prod_name as v,
NULL as vn, NULL as vt FROM sh.products
UNION ALL
SELECT prod_id + 200000 as vid, 'category' as k, 1 as t,
prod_category as v, NULL as vn, NULL as vt FROM sh.products
UNION ALL
SELECT prod_id + 200000 as vid, 'subcategory' as k, 1 as t,
prod_subcategory as v, NULL as vn, NULL as vt FROM sh.products
UNION ALL
SELECT prod_id + 200000 as vid, 'listPrice' as k, 3 as t,
TO_CHAR(prod_list_price) as v, prod_list_price as vn, NULL as vt
FROM sh.products
UNION ALL
SELECT prod_id + 200000 as vid, 'sourceId' as k, 2 as t,
TO_CHAR(prod_id) as v, prod_id as vn, NULL as vt FROM sh.products
ORDER BY 1,2;
```



9) Prepare the nodes representing the customers, performing the UNPIVOT to transform columns into rows and formatting the result to respect the graph rules. This is a validation step testing the query only.

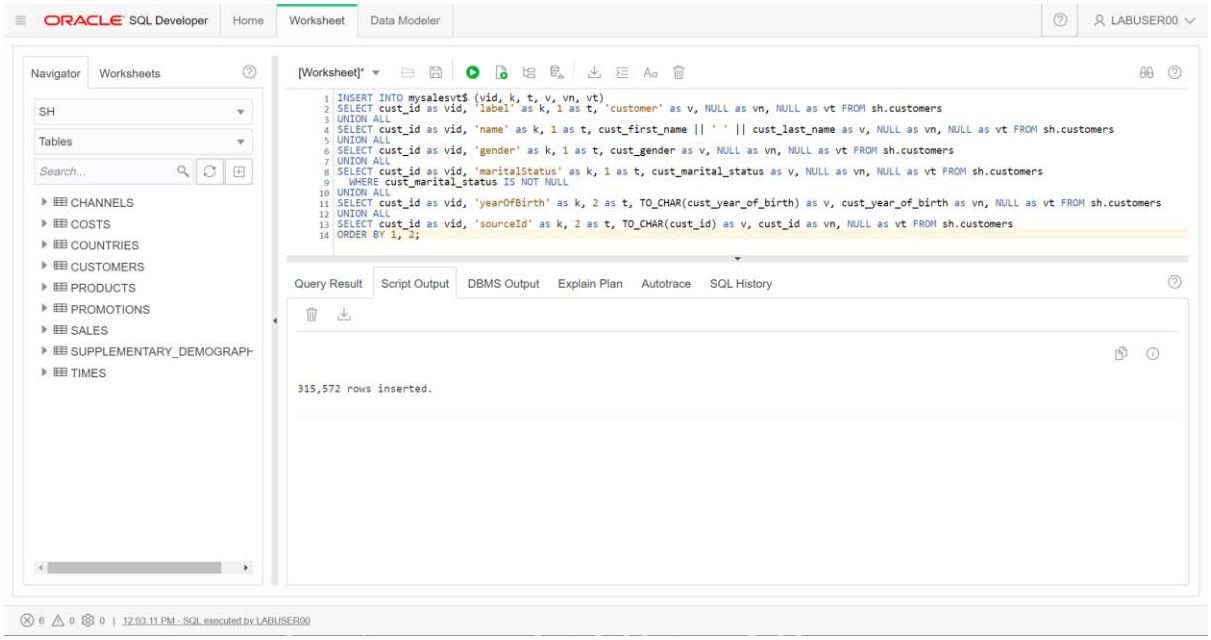
```
SELECT cust_id as vid, 'label' as k, 1 as t, 'customer' as v, NULL
as vn, NULL as vt FROM sh.customers
UNION ALL
SELECT cust_id as vid, 'name' as k, 1 as t, cust_first_name || ' '
|| cust_last_name as v, NULL as vn, NULL as vt FROM sh.customers
UNION ALL
SELECT cust_id as vid, 'gender' as k, 1 as t, cust_gender as v, NULL
as vn, NULL as vt FROM sh.customers
UNION ALL
SELECT cust_id as vid, 'maritalStatus' as k, 1 as t,
cust_marital_status as v, NULL as vn, NULL as vt FROM sh.customers
  WHERE cust_marital_status IS NOT NULL
UNION ALL
SELECT cust_id as vid, 'yearOfBirth' as k, 2 as t,
TO_CHAR(cust_year_of_birth) as v, cust_year_of_birth as vn, NULL as
vt FROM sh.customers
UNION ALL
SELECT cust_id as vid, 'sourceId' as k, 2 as t, TO_CHAR(cust_id) as
v, cust_id as vn, NULL as vt FROM sh.customers
ORDER BY 1, 2;
```

The "ORDER BY" is there to help highlighting the fact that a single node has multiple rows repeating the ID. When a property isn't defined it is skipped, the graph doesn't deal well with NULL vs not defined.



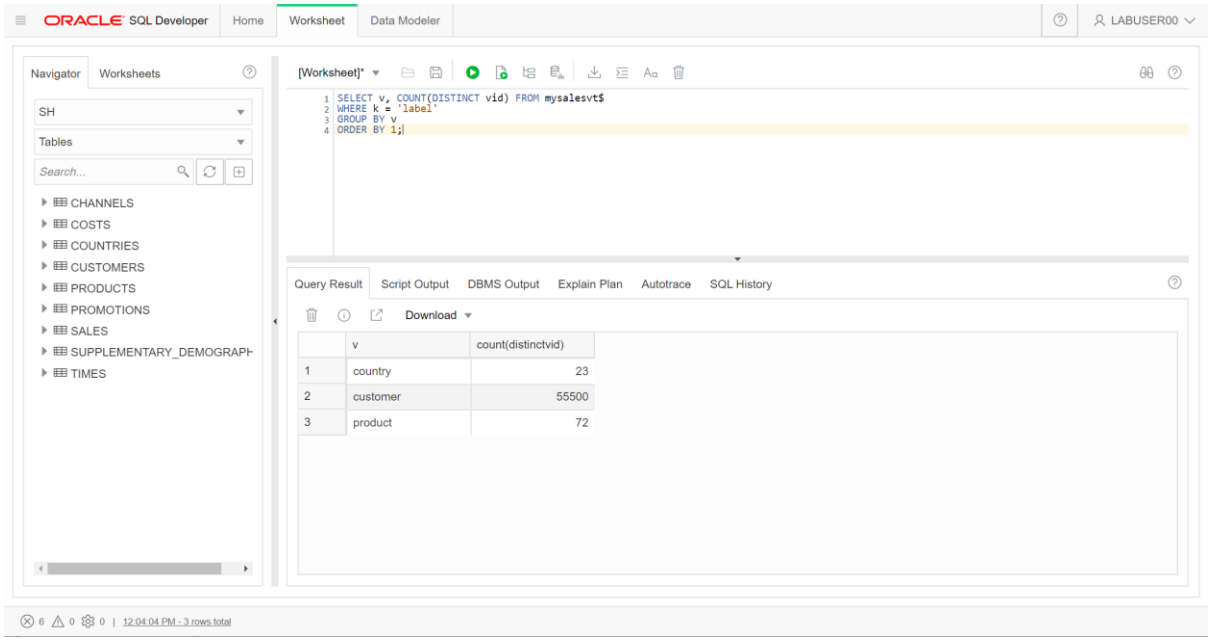
10) Insert the rows representing the customers nodes in the table.

```
INSERT INTO mysalesvt$ (vid, k, t, v, vn, vt)
SELECT cust_id as vid, 'label' as k, 1 as t, 'customer' as v, NULL
as vn, NULL as vt FROM sh.customers
UNION ALL
SELECT cust_id as vid, 'name' as k, 1 as t, cust_first_name || ' '
|| cust_last_name as v, NULL as vn, NULL as vt FROM sh.customers
UNION ALL
SELECT cust_id as vid, 'gender' as k, 1 as t, cust_gender as v, NULL
as vn, NULL as vt FROM sh.customers
UNION ALL
SELECT cust_id as vid, 'maritalStatus' as k, 1 as t,
cust_marital_status as v, NULL as vn, NULL as vt FROM sh.customers
  WHERE cust_marital_status IS NOT NULL
UNION ALL
SELECT cust_id as vid, 'yearOfBirth' as k, 2 as t,
TO_CHAR(cust_year_of_birth) as v, cust_year_of_birth as vn, NULL as
vt FROM sh.customers
UNION ALL
SELECT cust_id as vid, 'sourceId' as k, 2 as t, TO_CHAR(cust_id) as
v, cust_id as vn, NULL as vt FROM sh.customers
ORDER BY 1, 2;
```

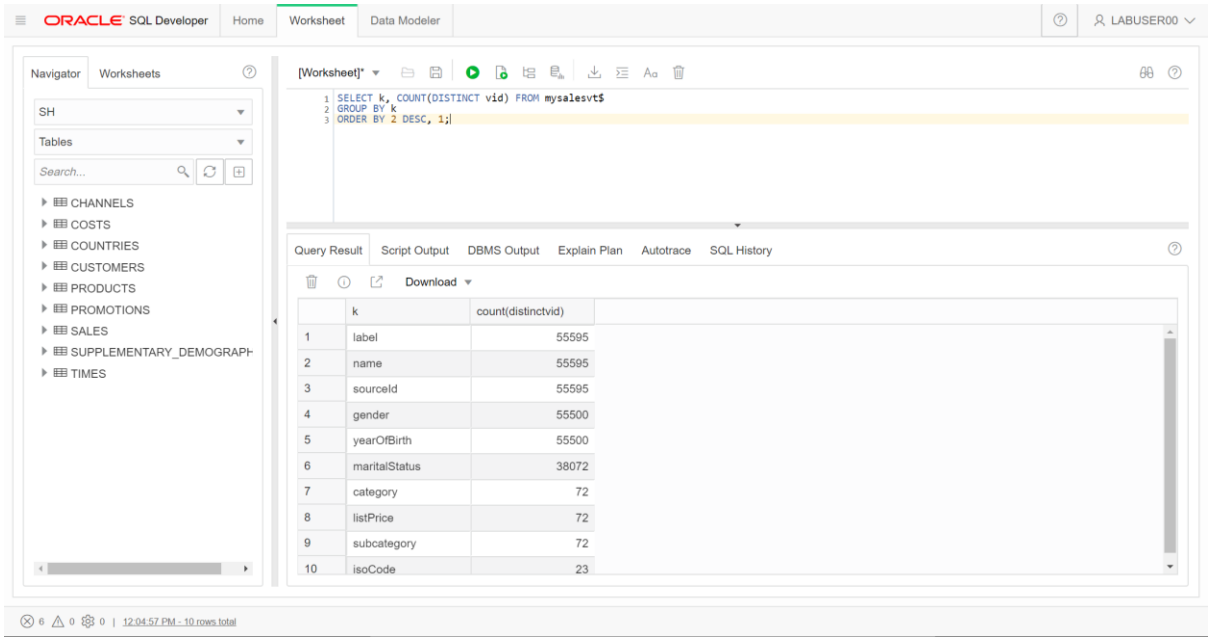


11) Execute some control queries on the nodes table to validate the content: number of nodes by label and number of nodes by property.

```
SELECT v, COUNT(DISTINCT vid) FROM mysalesvt$
WHERE k = 'label'
GROUP BY v
ORDER BY 1;
```

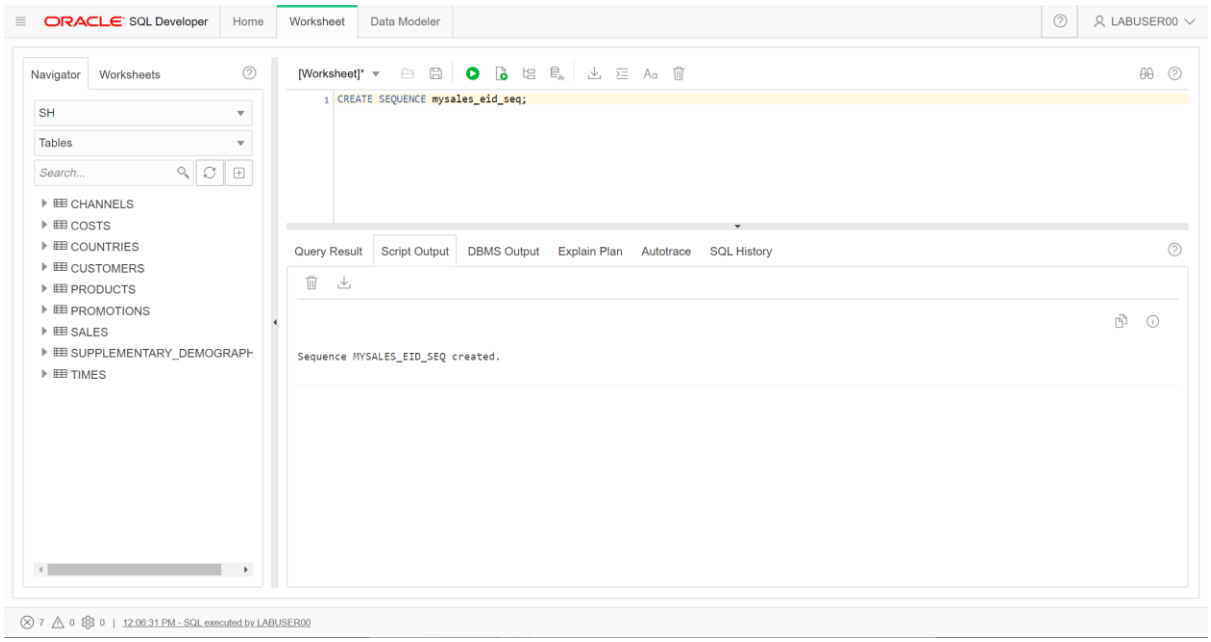



```
SELECT k, COUNT(DISTINCT vid) FROM mysalesvt$
GROUP BY k
ORDER BY 2 DESC, 1;
```



12) For the edges there isn't an existing ID in the table, therefore you can't use that as base. The solution is to use a sequence in the database. It will keep track of the last value returned and keep increment this value to generate unique numbers. A sequence can be used for the nodes IDs as well to avoid the offset workaround.

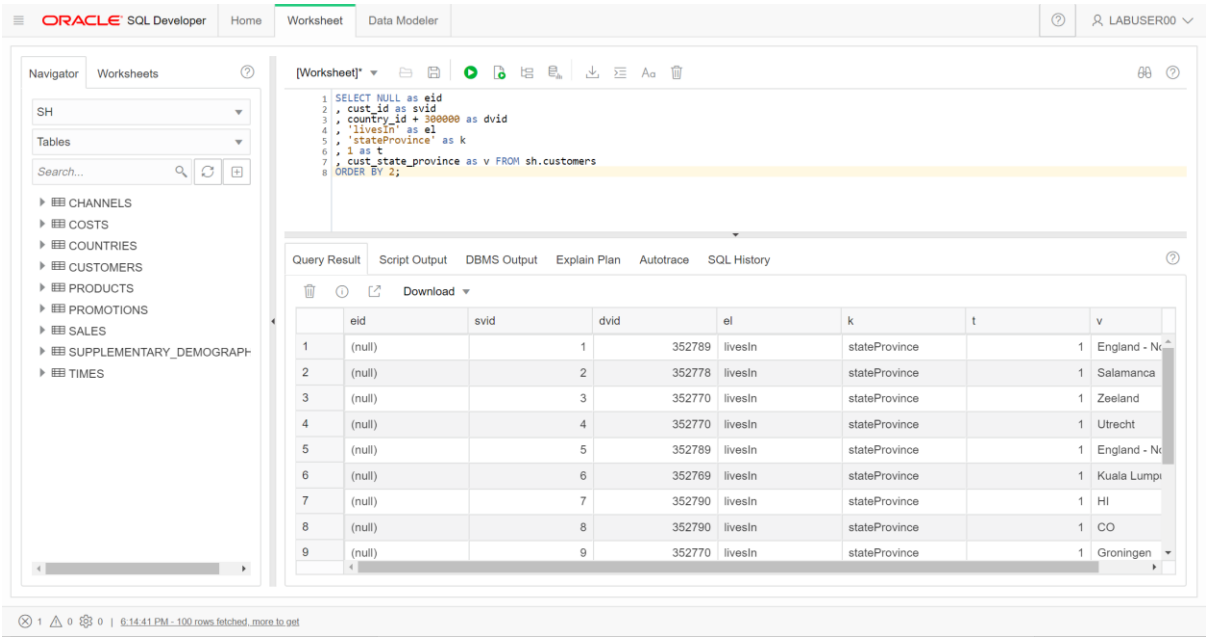
```
CREATE SEQUENCE mysales_eid_seq;
```



13) Prepare the edges representing the `(:customer) -[:livesIn]-> (:country)` edges, performing the UNPIVOT to transform columns into rows and formatting the result to respect the graph rules. This is a validation step testing the query only.

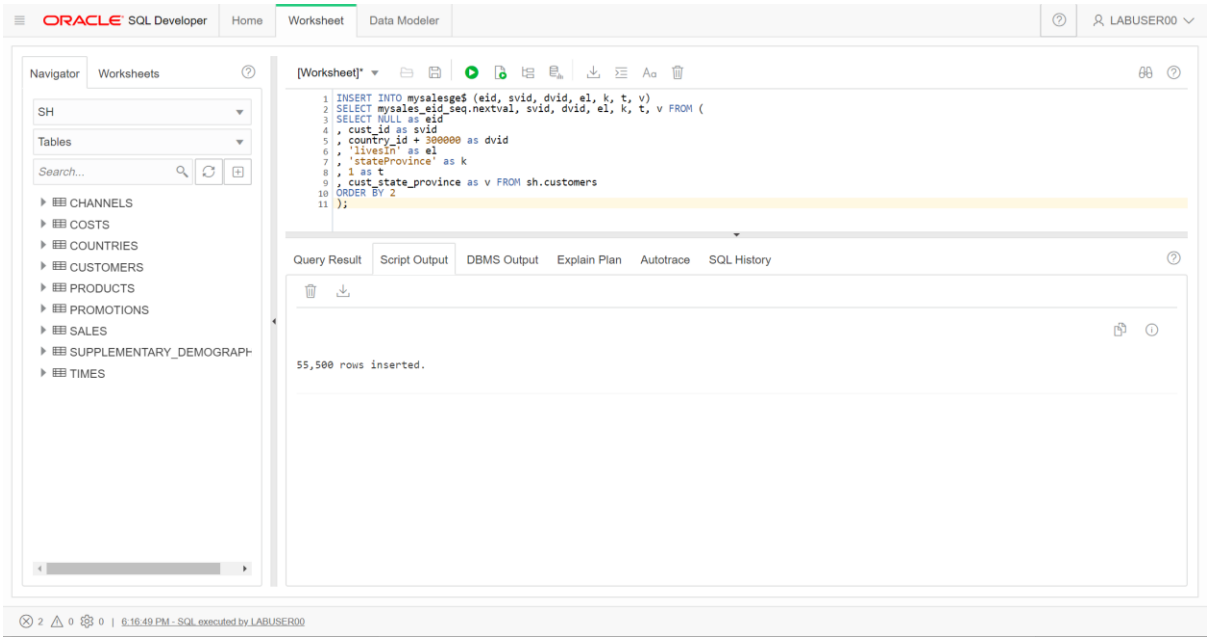
```
SELECT NULL as eid
, cust_id as svid
, country_id + 300000 as dvid
, 'livesIn' as el
, 'stateProvince' as k
, 1 as t
, cust_state_province as v FROM sh.customers
ORDER BY 2;
```

Do not use the sequence when performing the validation step as it would waste numbers and time for nothing. Also don't forget the offset you have applied to the IDs of the countries.



14) Insert the rows representing the `(:customer) -[:livesIn]-> (:country)` relationships into the table. Using the sequence this time, to generate a single IDs for every single edge.

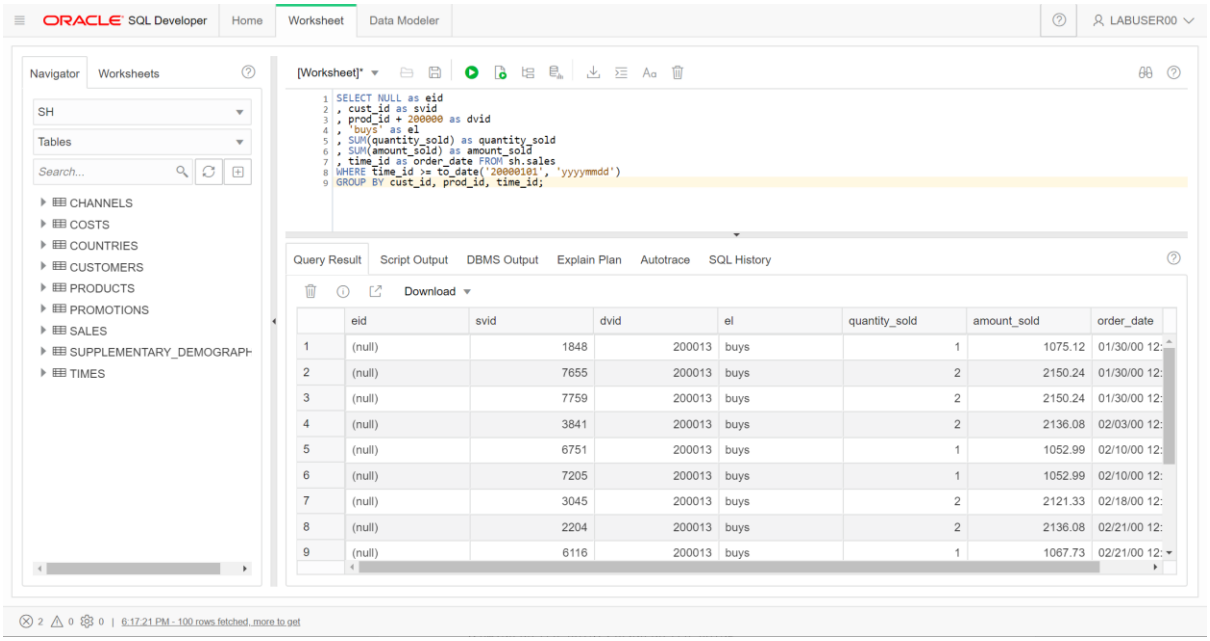
```
INSERT INTO mysalesge$ (eid, svid, dvid, el, k, t, v)
SELECT mysales_eid_seq.nextval, svid, dvid, el, k, t, v FROM (
SELECT NULL as eid
, cust_id as svid
, country_id + 300000 as dvid
, 'livesIn' as el
, 'stateProvince' as k
, 1 as t
, cust_state_province as v FROM sh.customers
ORDER BY 2
);
```



15) The rows representing the edges `(:customer) -[:buys]-> (:product)` require an extra step. There are multiple attributes you want to collect as properties, these will be multiple rows in the table. But these rows must all share the same edge ID generated by the sequence. For this a temporary table will be created where an ID using the sequence is going to be assigned to every entry before to unpivot its columns. This is a validation query to check what the temporary table will look like.

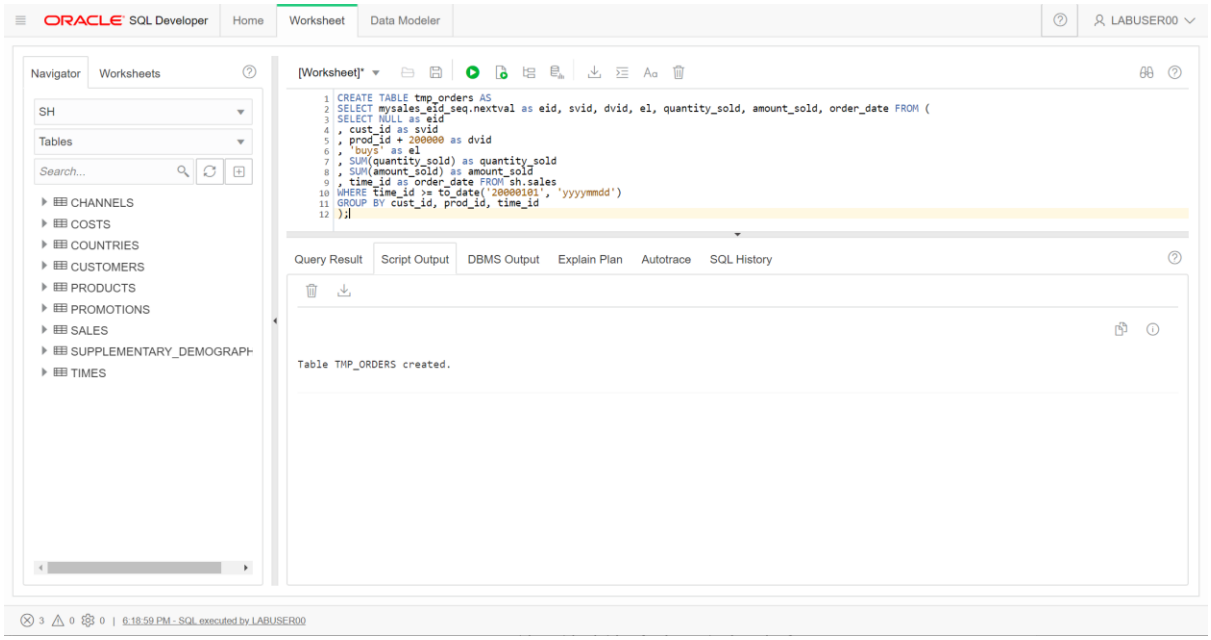
```
SELECT NULL as eid
, cust_id as svid
, prod_id + 200000 as dvid
, 'buys' as el
, SUM(quantity_sold) as quantity_sold
, SUM(amount_sold) as amount_sold
, time_id as order_date FROM sh.sales
WHERE time_id >= to_date('20000101', 'yyyymmdd')
GROUP BY cust_id, prod_id, time_id;
```

Do not forget to apply the offset on the products IDs. The query has a filter to only take half of the sales to keep the graph to a smaller size to make it faster for the lab environment.

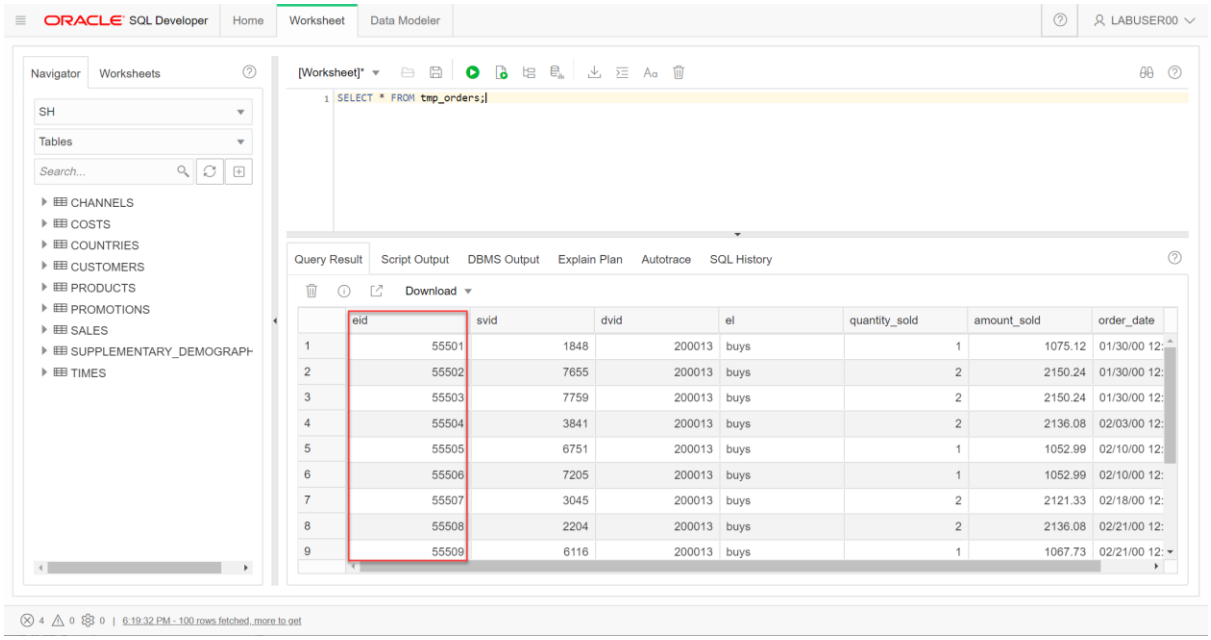


```
CREATE TABLE tmp_orders AS
SELECT mysales_eid_seq.nextval as eid, svid, dvid, el,
quantity_sold, amount_sold, order_date FROM (
SELECT NULL as eid
, cust_id as svid
, prod_id + 200000 as dvid
, 'buys' as el
, SUM(quantity_sold) as quantity_sold
, SUM(amount_sold) as amount_sold
, time_id as order_date FROM sh.sales
WHERE time_id >= to_date('20000101', 'yyyymmdd')
GROUP BY cust_id, prod_id, time_id
);
```

The temporary table create used the sequence to populate the "eid" column with unique IDs.

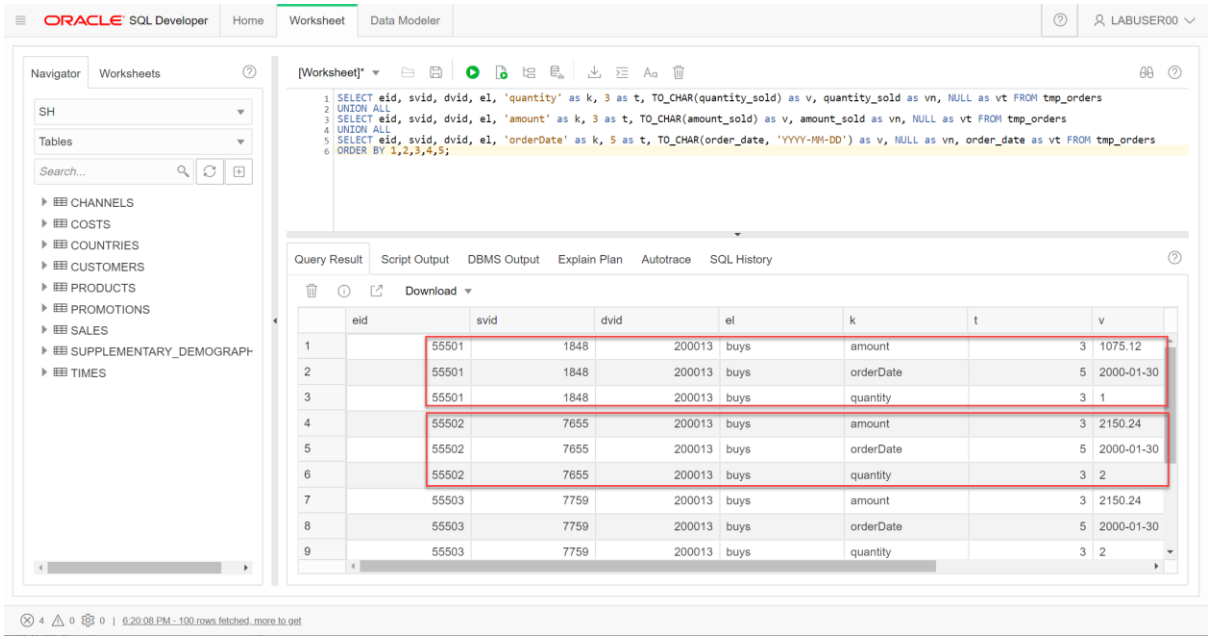



```
SELECT * FROM tmp_orders;
```



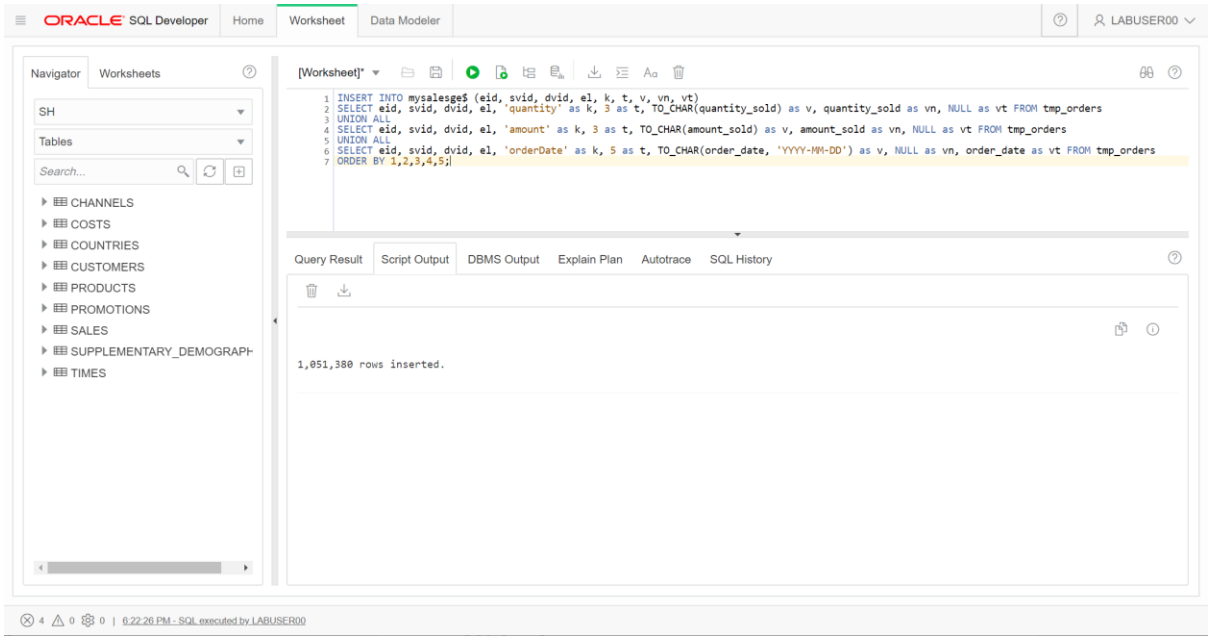
16) Prepare the edges representing the `(:customer) -[:buys]-> (:product)` relationships using the temporary table.

```
SELECT eid, svid, dvid, el, 'quantity' as k, 3 as t,
TO_CHAR(quantity_sold) as v, quantity_sold as vn, NULL as vt FROM
tmp_orders
UNION ALL
SELECT eid, svid, dvid, el, 'amount' as k, 3 as t,
TO_CHAR(amount_sold) as v, amount_sold as vn, NULL as vt FROM
tmp_orders
UNION ALL
SELECT eid, svid, dvid, el, 'orderDate' as k, 5 as t,
TO_CHAR(order_date, 'YYYY-MM-DD') as v, NULL as vn, order_date as vt
FROM tmp_orders
ORDER BY 1,2,3,4,5;
```



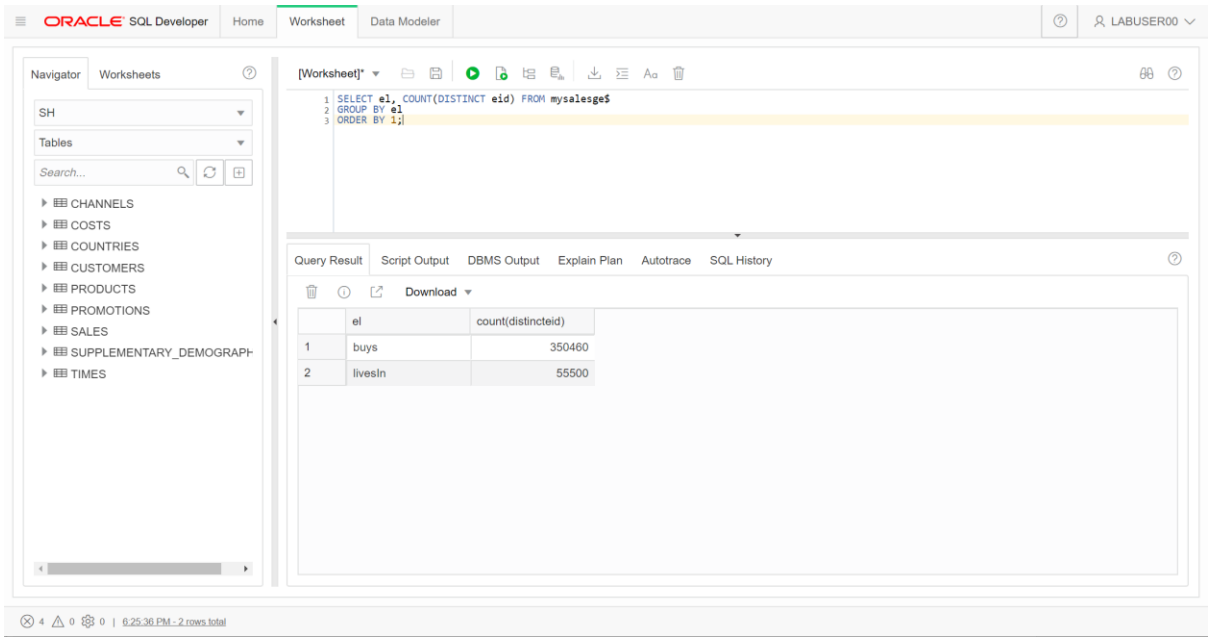
17) Insert the rows representing the `(:customer) -[:buys]-> (:product)` relationships.

```
INSERT INTO mysalesge$ (eid, svid, dvid, el, k, t, v, vn, vt)
SELECT eid, svid, dvid, el, 'quantity' as k, 3 as t,
TO_CHAR(quantity_sold) as v, quantity_sold as vn, NULL as vt FROM
tmp_orders
UNION ALL
SELECT eid, svid, dvid, el, 'amount' as k, 3 as t,
TO_CHAR(amount_sold) as v, amount_sold as vn, NULL as vt FROM
tmp_orders
UNION ALL
SELECT eid, svid, dvid, el, 'orderDate' as k, 5 as t,
TO_CHAR(order_date, 'YYYY-MM-DD') as v, NULL as vn, order_date as vt
FROM tmp_orders
ORDER BY 1,2,3,4,5;
```

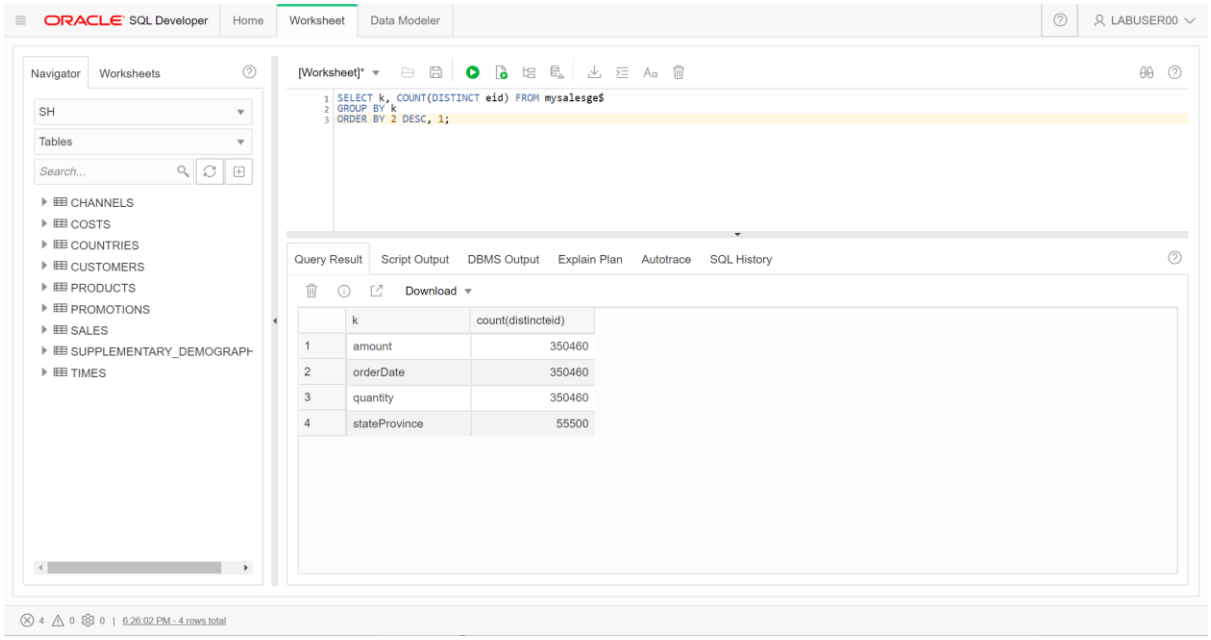


18) Check the edges generated, counting them by label and property.

```
SELECT el, COUNT(DISTINCT eid) FROM mysalesge$
GROUP BY el
ORDER BY 1;
```



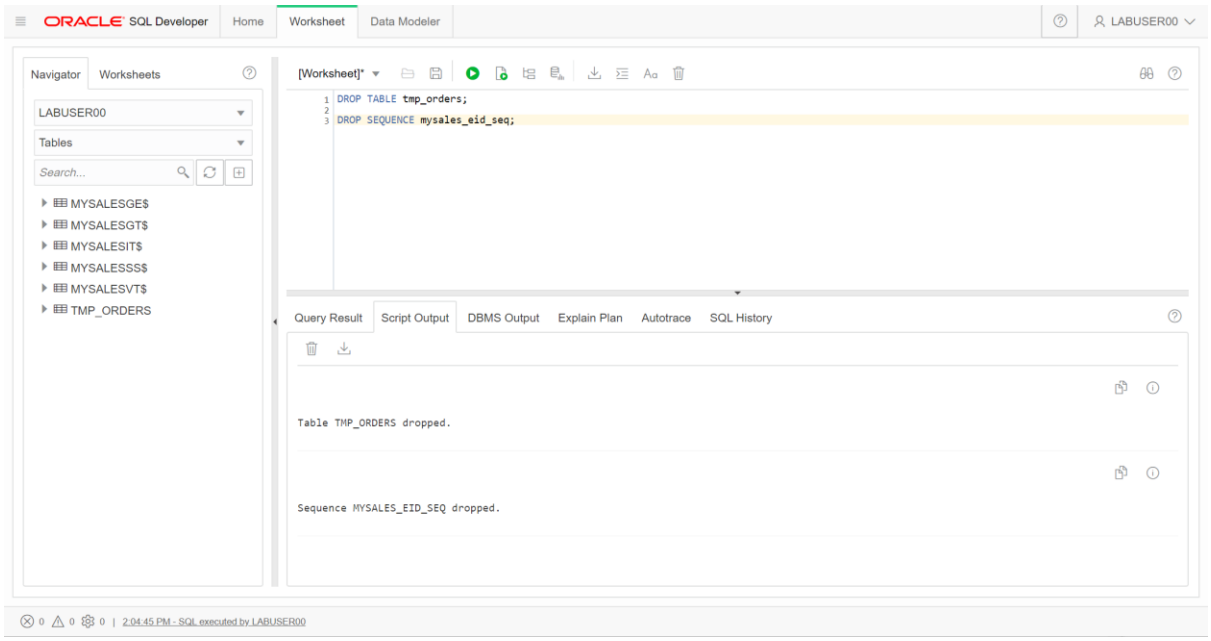

```
SELECT k, COUNT(DISTINCT eid) FROM mysalesge$
GROUP BY k
ORDER BY 2 DESC, 1;
```



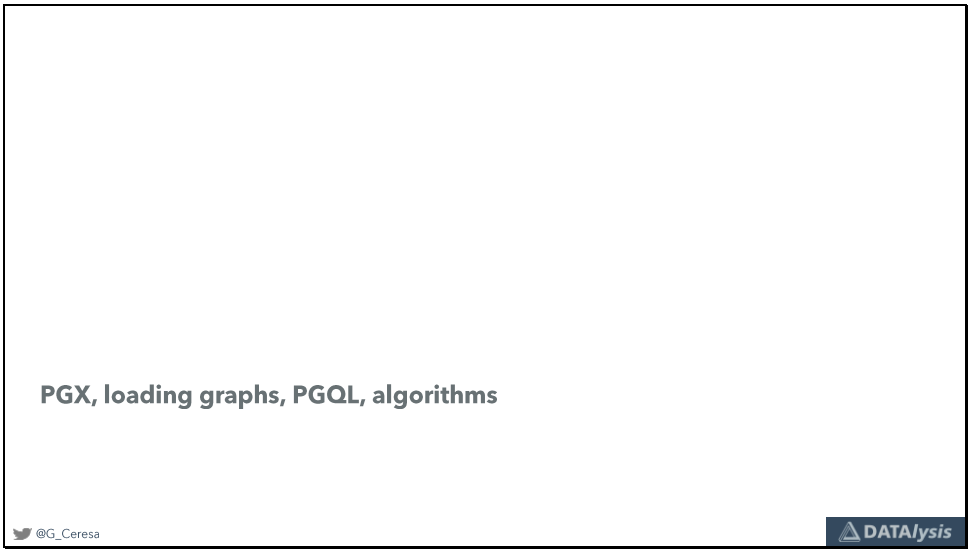
19) Clean up the temporary table and also the sequence as the graph is fully loaded.

```
DROP TABLE tmp_orders;

DROP SEQUENCE mysales_eid_seq;
```



Slide 43



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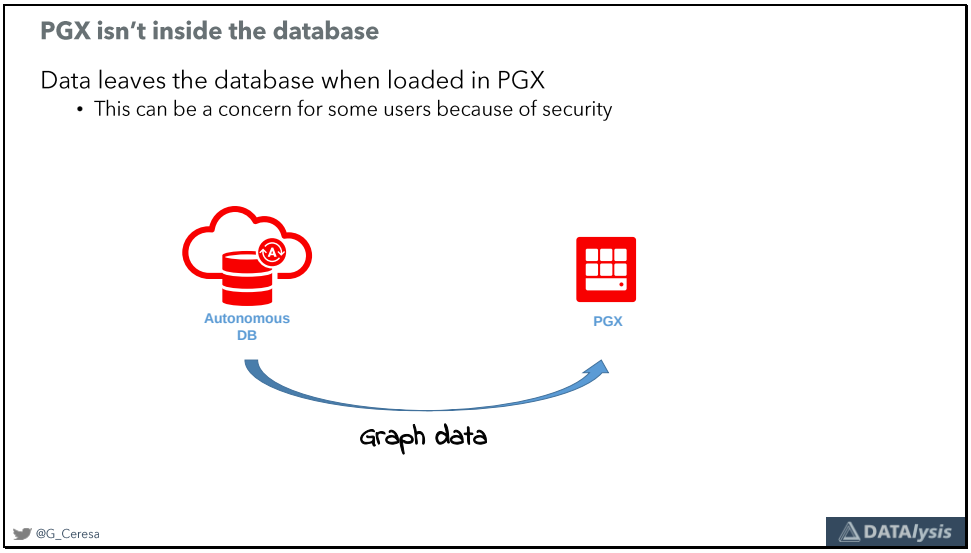

PGX, the "engine" powering property graph in Oracle, is a separate process than the database. This means that when a graph is loaded in PGX, the data is leaving the database to be loaded into PGX:

Slide 45

Loading a graph in PGX

PGX is written in Java, to load a graph you have to use the existing Java packages

- The JavaDoc is the "bible"

Steps to load a graph (from any source):

- Create a *GraphConfigBuilder*, defining where to find the graph data
- Define all the properties for both nodes and edges you want to load
  (By default only the structure is loaded, no properties)
- "Build" the configuration
  (It will generate a JSON with all the settings)
- Call *readGraphWithProperties* passing the configuration JSON (can also be the path of a file containing the JSON)

It is not extremely intuitive, but still quite simple and there are examples provided with Oracle Graph Server 20.1.0 you can simply copy/paste the code from.

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The process to load a graph in PGX is mainly creating a configuration defining where the graph is stored. Define which properties you want to load. Build the configuration which simply takes all the settings and some defaults to generate a Json string. And finally you can load the graph by using that Json (or a path pointing to a file containing the Json).

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Loading a graph in PGX

Example of code:

```
var cfg = GraphConfigBuilder.forPropertyGraphRdbms()
.setName("graph_name")
.setJdbcUrl("jdbc:oracle:thin:@DB_host:DB_port/DB_service")
.setKeystoreAlias("") // this must be set or you get an error
.setUsername("DB_username")
.setPassword("DB_password")
.build();

var graph = session.readGraphWithProperties(cfg);
```

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A practical example looks like this.

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Loading a graph in PGX

For any property you want to load, on both nodes or edges, you must explicitely declare it in the *GraphConfigBuilder*.

```
.addEdgeProperty("property_name", PropertyType.STRING)
.addVertexProperty("property_name", PropertyType.DOUBLE)
```

The supported types (PropertyType) are:

```
BOOLEAN, DOUBLE, EDGE, FLOAT, INTEGER, LOCAL_DATE, LONG,
POINT2D, STRING, TIME, TIME_WITH_TIMEZONE, TIMESTAMP,
TIMESTAMP_WITH_TIMEZONE, VERTEX
```

(the JavaDoc is the reference)

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For the properties you will have to define them one by one, setting their name and type.

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Loading a graph in PGX

With a graph stored in the database you can generate the commands to load all the properties directly in the database

- Select from the $GE and $VT table all the properties keys and their type, build the full command and concatenate all with LISTAGG

```
WITH properties AS (
    SELECT DISTINCT k, t, 'Vertex' AS kind FROM mysalesvt$
    UNION ALL
    SELECT DISTINCT k, t, 'Edge' AS kind FROM mysalesge$
), cfg AS (
    SELECT '.add' || kind || 'Property("' || k || '",PropertyType.' ||
    CASE
        WHEN t = 1 THEN 'STRING' WHEN t = 2 THEN 'INTEGER' WHEN t = 3 THEN 'FLOAT'
        WHEN t = 4 THEN 'DOUBLE' WHEN t = 7 THEN 'LONG' WHEN t = 5 THEN 'LOCAL_DATE'
        WHEN t = 6 THEN 'BOOLEAN'
    END || ')' AS prop
    FROM properties
    WHERE k IS NOT NULL
) SELECT LISTAGG(prop,'') WITHIN GROUP(ORDER BY prop) FROM cfg;
```

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When using a database as storage for the graph you can generate the whole list of configuration for all the properties by a SQL query on your database.

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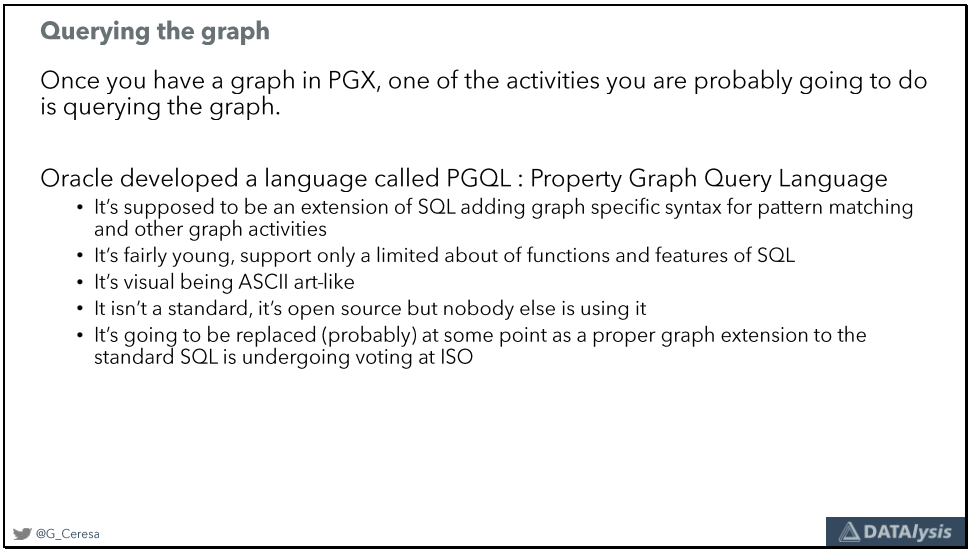

Loading a graph is nice but useless if you don't use it. The most common things is querying the graph by using PGQL, the property graph query language.

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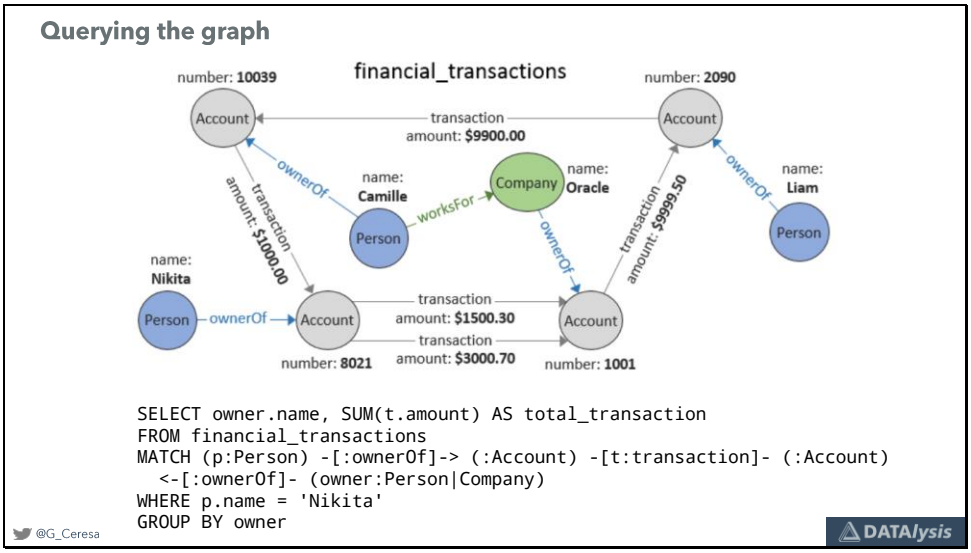

An example of PGQL on a sample graph: you can easily follow the logic of the MATCH condition in the above graph.
You can find all the details about PGQL at http://pgql-lang.org/ .

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Querying the graph

Practically in JShell it will be done in this way:

```
var pgql = "SELECT c.name, p.name, b.orderDate, b.amount,
b.quantity WHERE (c:customer) -[b:buys]-> (p:product) LIMIT
10";


PgqlResultSet resultSet = graph.queryPgql(pgql);


for (var result : resultSet) {
  print(result.getString(1) + " bought " +
        result.getString("p.name") + ": qty=" +
        result.getFloat("b.quantity") + " on " +
        result.getDate(3));
}
```

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In the PGX client JShell interface you will need to follow the rules of Java, the language used to interact with PGX in the JShell.

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Executing Graph algorithms

Querying the graph is one thing, but one of the real benefits with a graph are all the graph algorithms. They can provide answers to complex questions rapidly.

PGX comes with a set of about 60 algorithms available out of the box.

You can write new algorithms:

- Green-Marl
- Java

For many the source code is provided, making it easy to customize.

Built-In Algorithms

PGX includes a wide selection of optimized graph algorithms that can be invoked through the Analyst. The following table provides an overview of the available algorithms, grouped by category.

Category	Algorithms
Classic graph algorithms	Prim's Algorithm
Community detection	Conductance Minimization (Soman and Narang Algorithm), Infomap, Label Propagation
Connected components	Strongly Connected Components, Weakly Connected Components (WCC)
Link prediction	WTF (Whom To Follow) Algorithm
Matrix factorization	Matrix Factorization
Other	Graph Traversal Algorithms
Path finding	Bellman-Ford Algorithms, Bidirectional Dijkstra Algorithms, Dijkstra Algorithms, Fattest Path, Hop Distance Algorithms
Ranking and walking	Closeness Centrality Algorithms, Degree Centrality Algorithms, Eigenvector Centrality, Hyperlink-Induced Topic Search (HITS), PageRank Algorithms, Random Walk with Restart, Stochastic Approach for Link-Structure Analysis (SALSA) Algorithms, Vertex Betweenness Centrality Algorithms
Structure evaluation	Adamic-Adar index, Conductance, Cycle Detection Algorithms, Degree Distribution Algorithms, Eccentricity Algorithms, K-Core, Local Clustering Coefficient (LCC), Modularity, Partition Conductance, Reachability Algorithms, Topological Ordering Algorithms, Triangle Counting

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Another common activity is to execute algorithms. Oracle PGX comes with many algorithms available out of the box. You can also write your own if you need.

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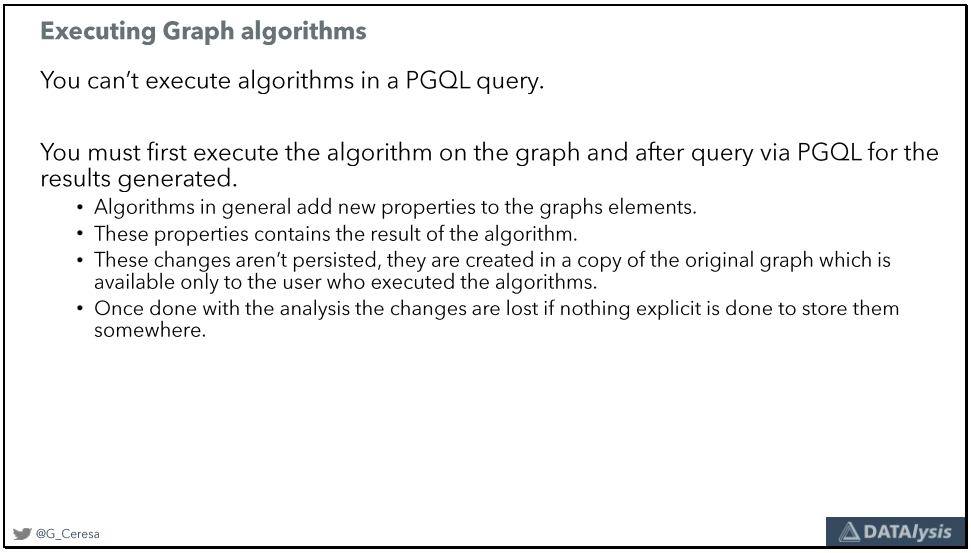

Algorithms aren't executed via a PGQL query. You execute them in an "analyst" session and you then query the graph to get the result of the algorithms.

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Executing Graph algorithms

An example of PageRank calculation on a graph:

```
var analyst = session.createAnalyst();

var pagerank = analyst.pagerank(graph2);
print(pagerank);

var query = "SELECT v, v.name, v."+pagerank.getName()+" WHERE
(v:product) ORDER BY v."+pagerank.getName()+" DESC LIMIT 10";
print(query);
var resultSet = graph2.queryPgql(query);
for (var result : resultSet) {
    print("node: "+result.getString(2)+" has pagerank =
"+result.getDouble(3));
}
resultSet.close();
```

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An example code to execute a page rank algorithm. Most algorithms add temporary properties to nodes and/or edges in the graph holding the results. The name of these properties can be retrieved by reading it from the returned value at the executing of the algorithm.

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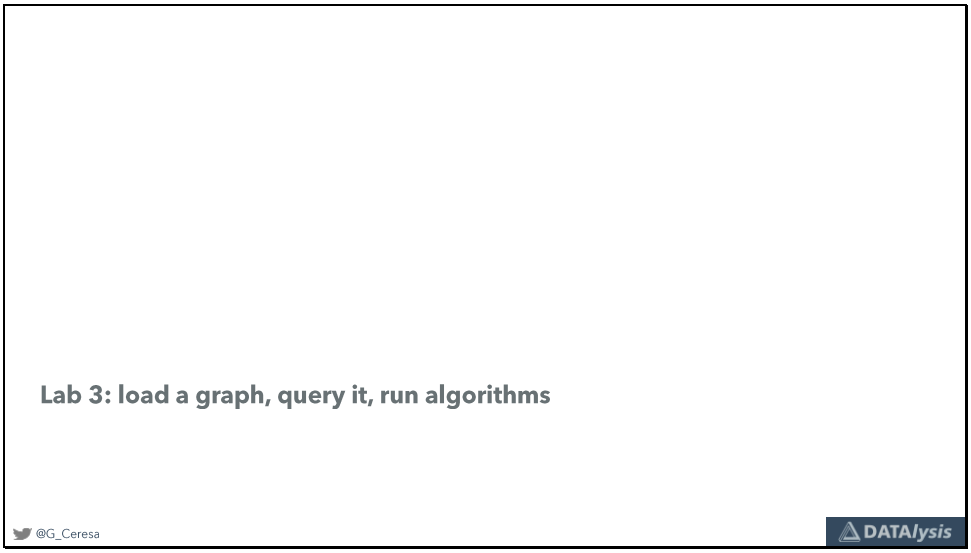
Lab 3: load a graph, query it, run algorithms
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Lab 3: Load graph in PGX and query it

> **Target**
>
> In this lab you will load a graph stored in a database into PGX, run PGQL queries and execute algorithms on it.

The Oracle Graph client comes with either a Groovy or JShell command line. For this Lab you will use a JupyterLab notebook on top of the Java Oracle Graph client.

The syntax and commands you can use are Java, they will work in the same way (or very close to) in the client itself.

The credentials for JupyterLab are the one provided.

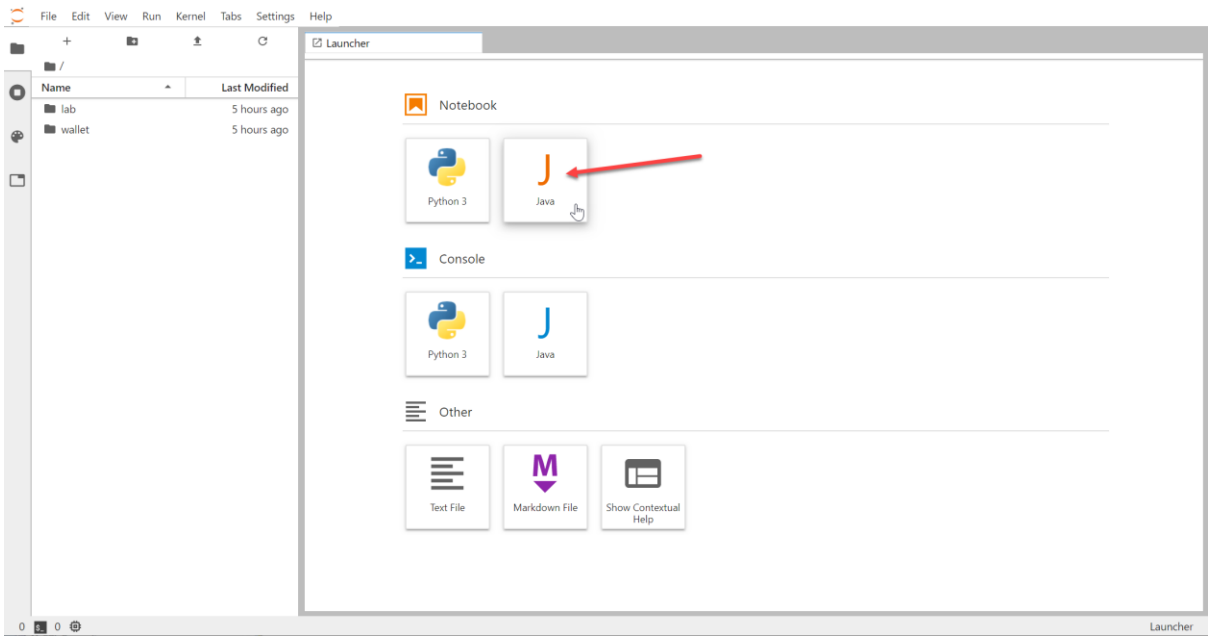
Basic syntax rules

Every variable must be defined either with the real type (int, String, PgxSession etc.) or with the generic "var" keyword.

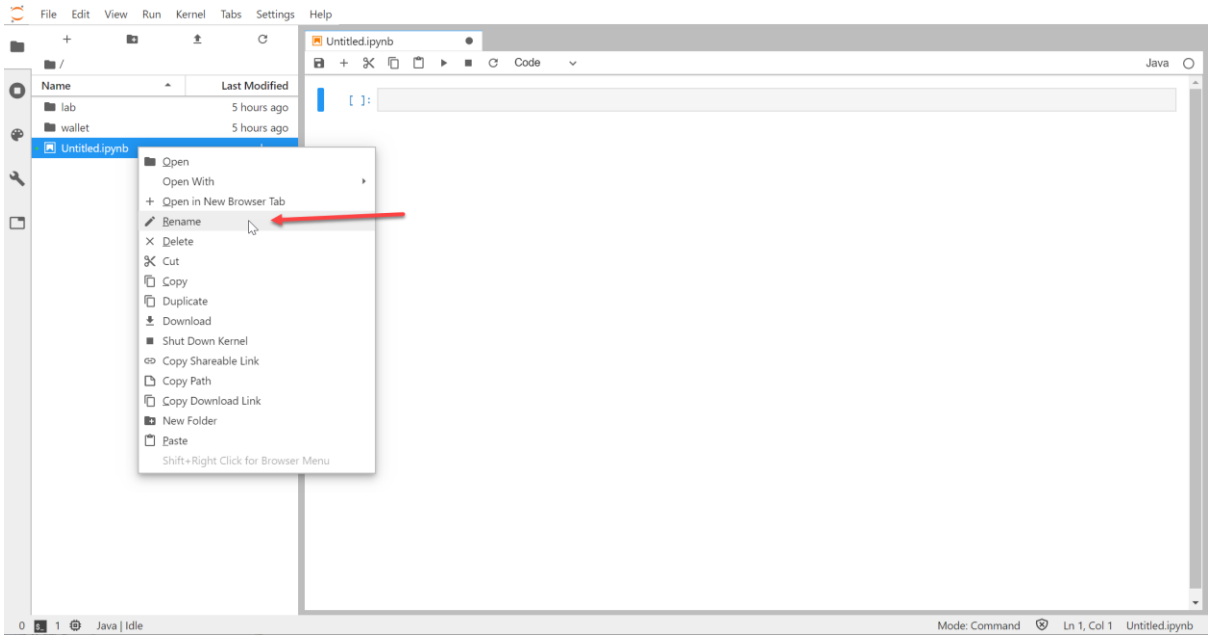
Commands must end with a ';', the last command or single-command cells will also work, but it's better to follow the rule to always end a command with ';'.

1) Create a new notebook based on Java.

Python could be used as well, but it would add a second layer of complexity with Python on top of Java using JPype. In this Lab you are going to stick to Java which is as close the PGX as possible.

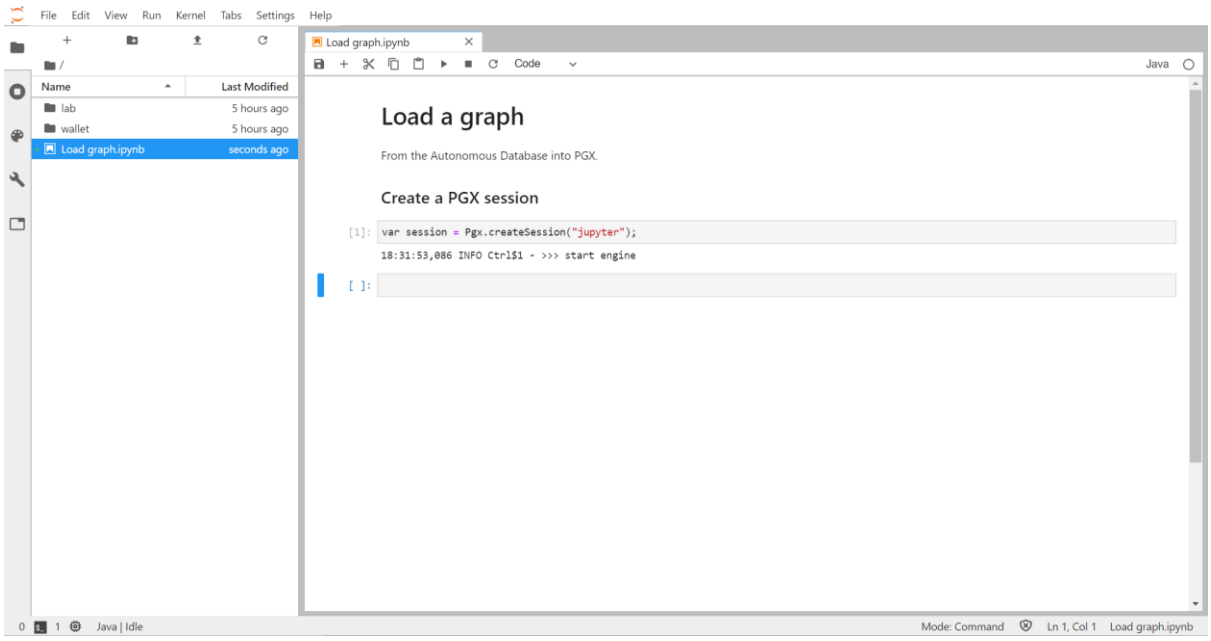


It's a good practice to rename things in a way to describe what they are about. In this case it's highly suggested you give a name to the notebook instead of "Untitled".



2) Create a PGX session

```
var session = Pgx.createSession("jupyter");
```



In the PGX client JShell session this variable is already initialized by default when the client session starts. The parameter to the function can be any kind of text, it's a way to identify sessions but in this case, a single user environment, it doesn't matter.

2) Create a configuration defining which graph to load

```
var cfg = GraphConfigBuilder.forPropertyGraphRdbms()
.setUsername("database_username")
.setPassword("database_password")
.setName("name_of_the_graph")
.setKeystoreAlias("")
.setJdbcUrl("jdbc:oracle:thin:@connection_descriptor?TNS_ADMIN=path_to_the_Autonomous_DB_wallet")
.build();
```

The values to uses are the following:

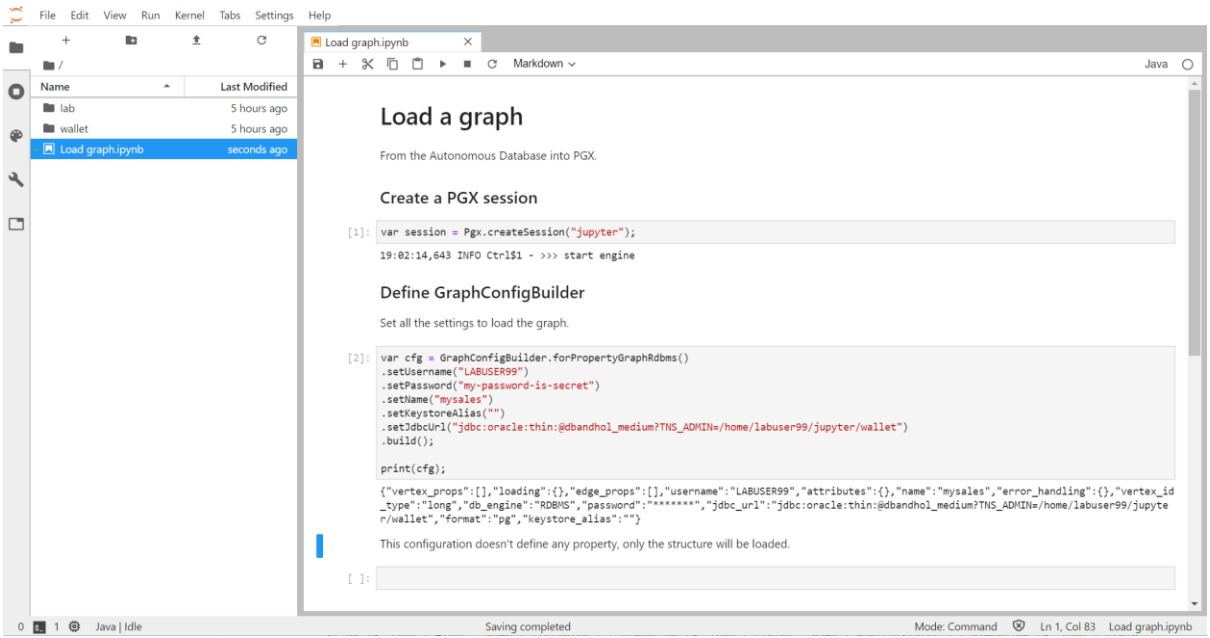
database_username: your username from the SQL Developer Web credentials

database_password: your password from the SQL Developer Web credentials

name_of_the_graph: the name you gave to you graph, match the tables names with suffixes "vt$", "ge$" etc.

connection_descriptor: database connection descriptor name as defined inside tnsnames.ora, for this lab the value is ***dbandhol_medium***

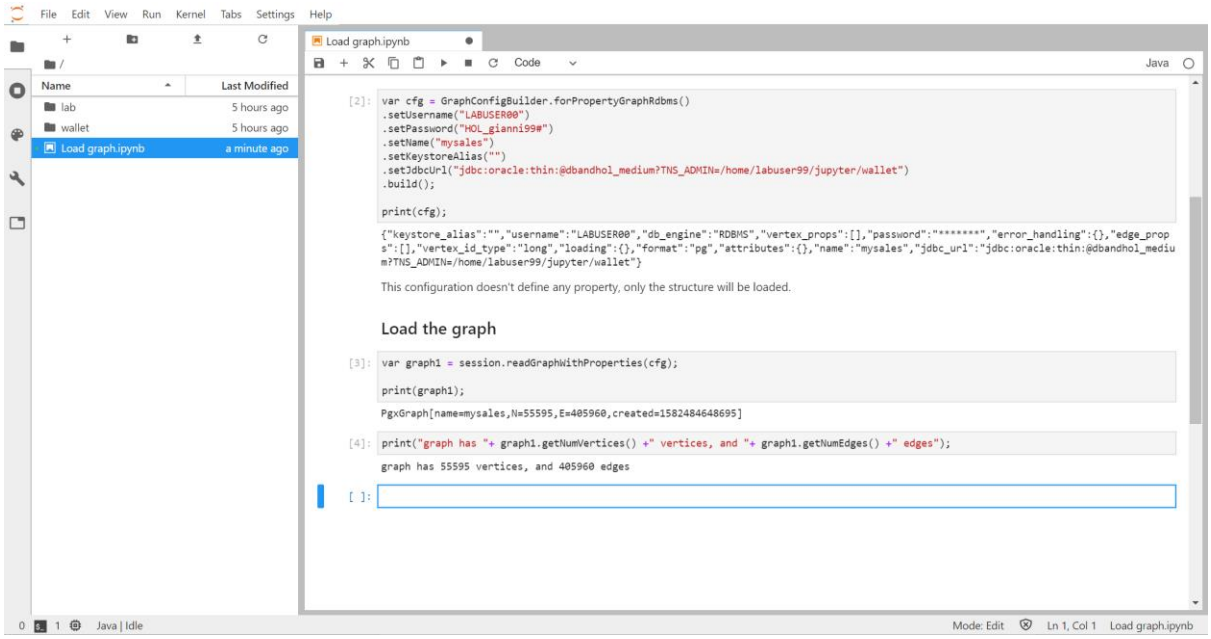
path_to_the_Autonomous_DB_wallet: path to the folder where the wallet you downloaded from the Autonomous Database has been extracted. For this labe the value is: ***/home/<your JupyterLab username>/jupyter/wallet*** . You will need to replace the <your JupyterLab username> by the value from the JupyterLab credentials.



Building this GraphConfigBuilder return the JSON representing the configuration.

3) Load the graph

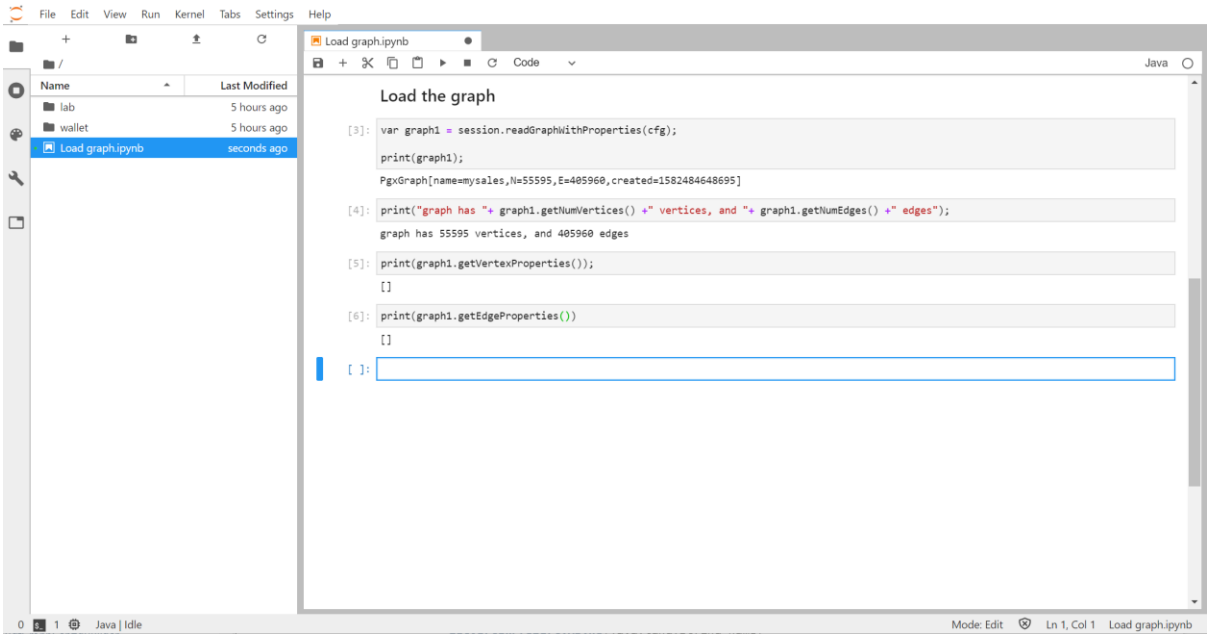
```
var graph1 = session.readGraphWithProperties(cfg);
```



Printing the `graph1` variable will return the graph name, the number of edges, the number of nodes and the timestamp when the graph was created.

4) Test the graph is really available

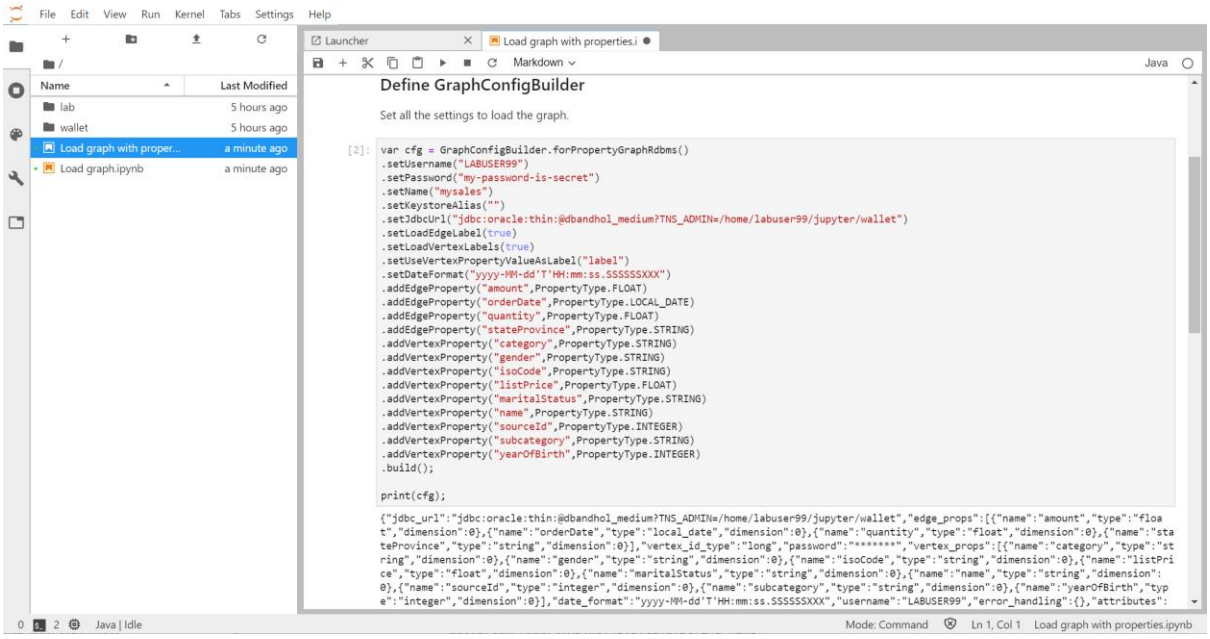
```
print("The graph has "+graph1.getNumVertices()+" nodes and
"+graph1.getNumEdges()+" edges.");

print(graph1.getVertexProperties());
print(graph1.getEdgeProperties());
```



When you list the properties for nodes and edges there is nothing returned. This is because the loaded graph was just the structure of nodes and edges, but not a single property has been loaded.

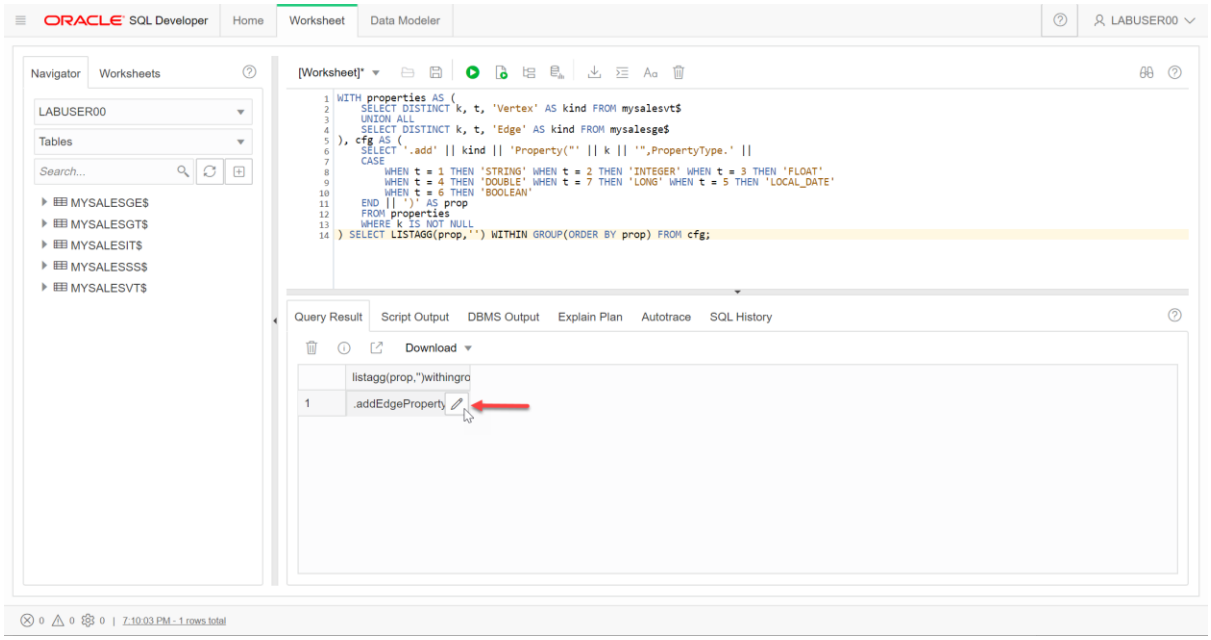
5) Load a graph with all the properties and the labels

```
var cfg = GraphConfigBuilder.forPropertyGraphRdbms()
.setUsername("database_username")
.setPassword("database_password")
.setName("name_of_the_graph")
.setKeystoreAlias("")
.setJdbcUrl("jdbc:oracle:thin:@connection_descriptor?TNS_ADMIN=path_
to_the_Autonomous_DB_wallet")
.setLoadEdgeLabel(true)
.setLoadVertexLabels(true)
... add all the properties ...
.build();
```

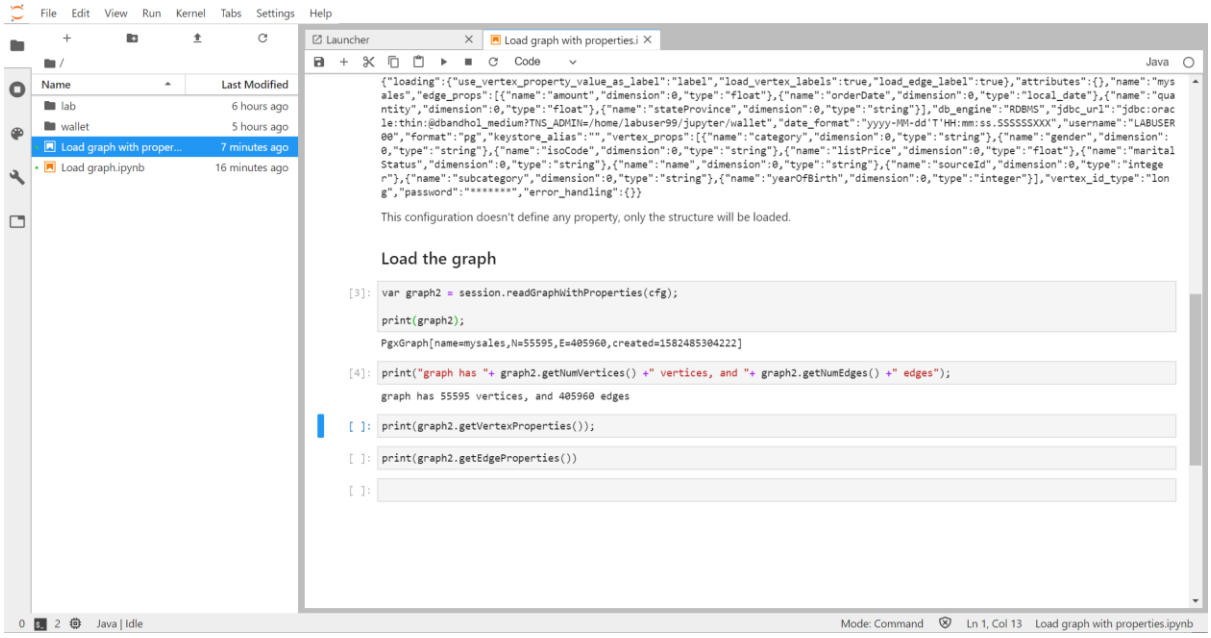


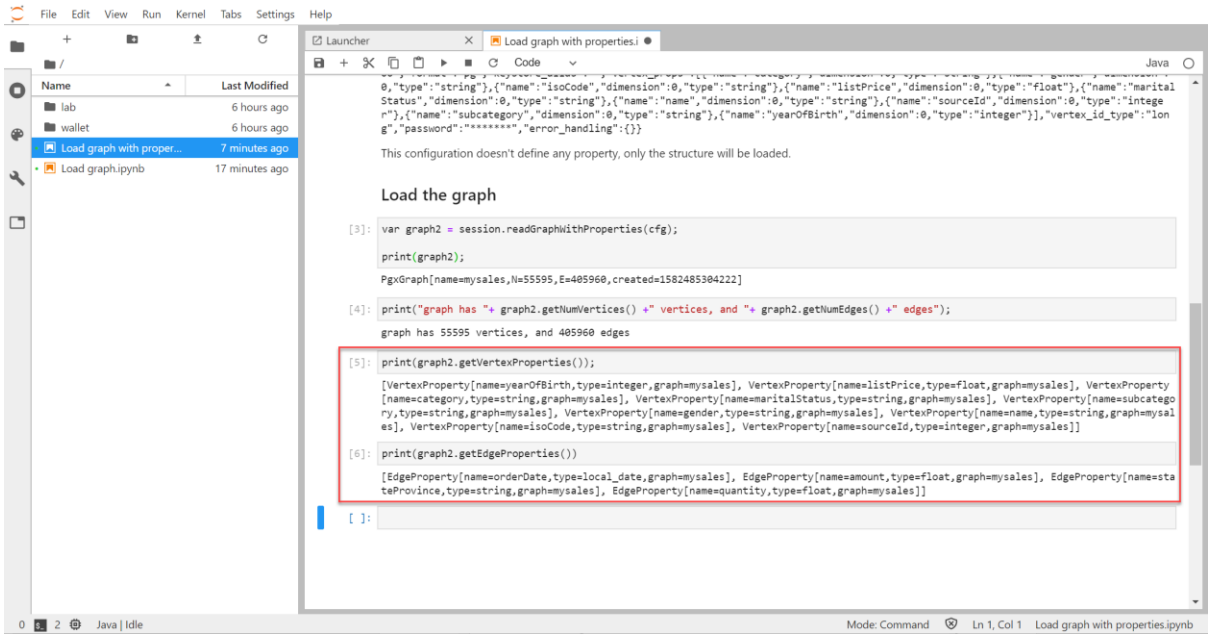
The list of all the properties can be generated by a query in the database using a query like the one below. A subset of properties can be loaded, it all depends on what are your needs. More properties = more resources = more time to load.

```
WITH properties AS (
    SELECT DISTINCT k, t, 'Vertex' AS kind FROM mysalesvt$
    UNION ALL
    SELECT DISTINCT k, t, 'Edge' AS kind FROM mysalesge$
), cfg AS (
    SELECT '.add' || kind || 'Property("' || k || '",PropertyType.'
||
    CASE
        WHEN t = 1 THEN 'STRING' WHEN t = 2 THEN 'INTEGER' WHEN t =
3 THEN 'FLOAT'
        WHEN t = 4 THEN 'DOUBLE' WHEN t = 7 THEN 'LONG' WHEN t = 5
THEN 'LOCAL_DATE'
        WHEN t = 6 THEN 'BOOLEAN'
    END || ')' AS prop
    FROM properties
    WHERE k IS NOT NULL
) SELECT LISTAGG(prop,'') WITHIN GROUP(ORDER BY prop) FROM cfg;
```



6) Test the graph is really available

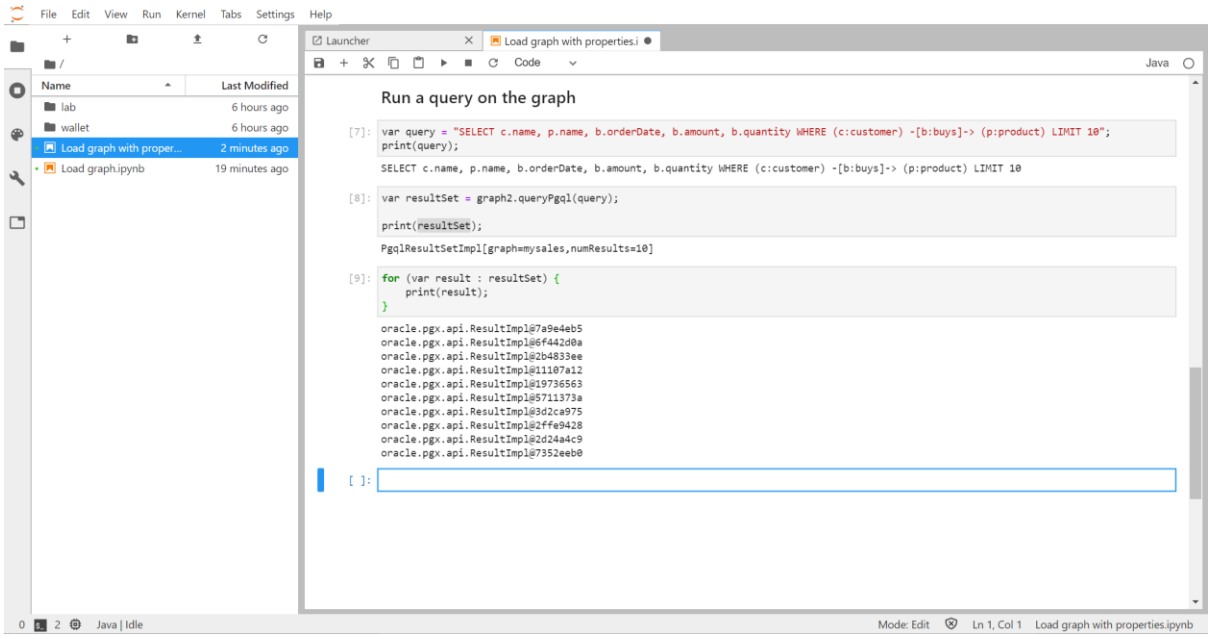




This time the graph return a list of properties for both nodes and edges. You can see that this list perfectly matches with all the properties defined in the configuration before to load the graph.

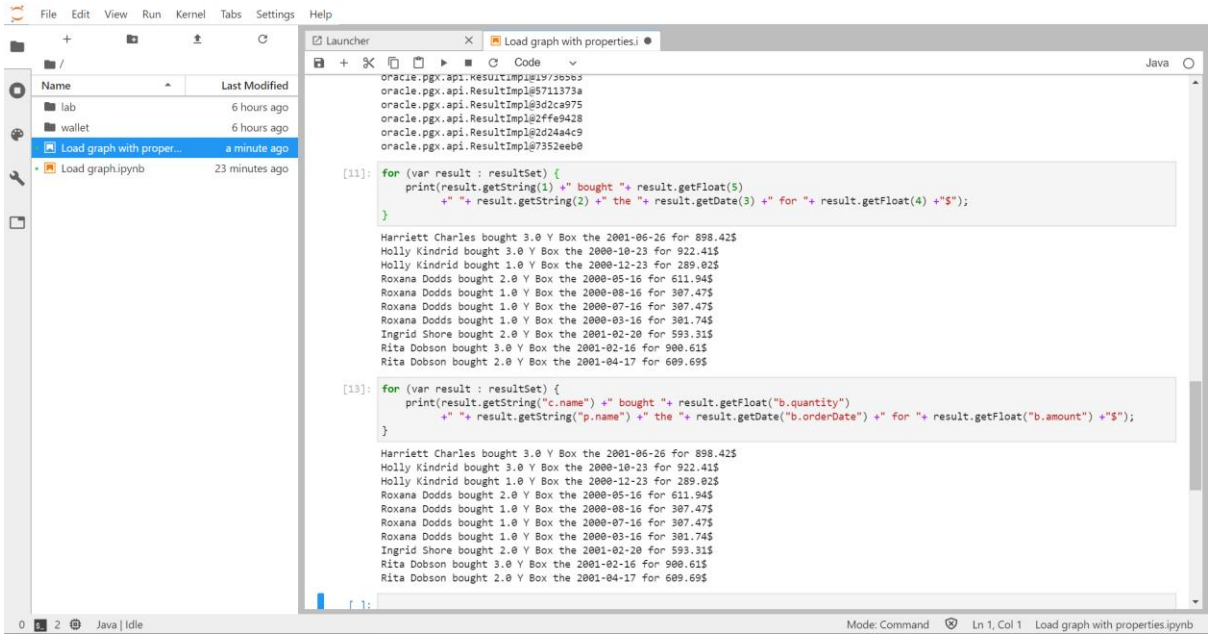
7) Query the graph

```
var query = "SELECT c.name, p.name, b.orderDate, b.amount,
b.quantity WHERE (c:customer) -[b:buys]-> (p:product) LIMIT 10";
print(query);

var resultSet = graph2.queryPgql(query);
print(resultSet);

for (var result : resultSet) {
    print(result);
}
```



The results of the query are objects referencing all the components of each row.

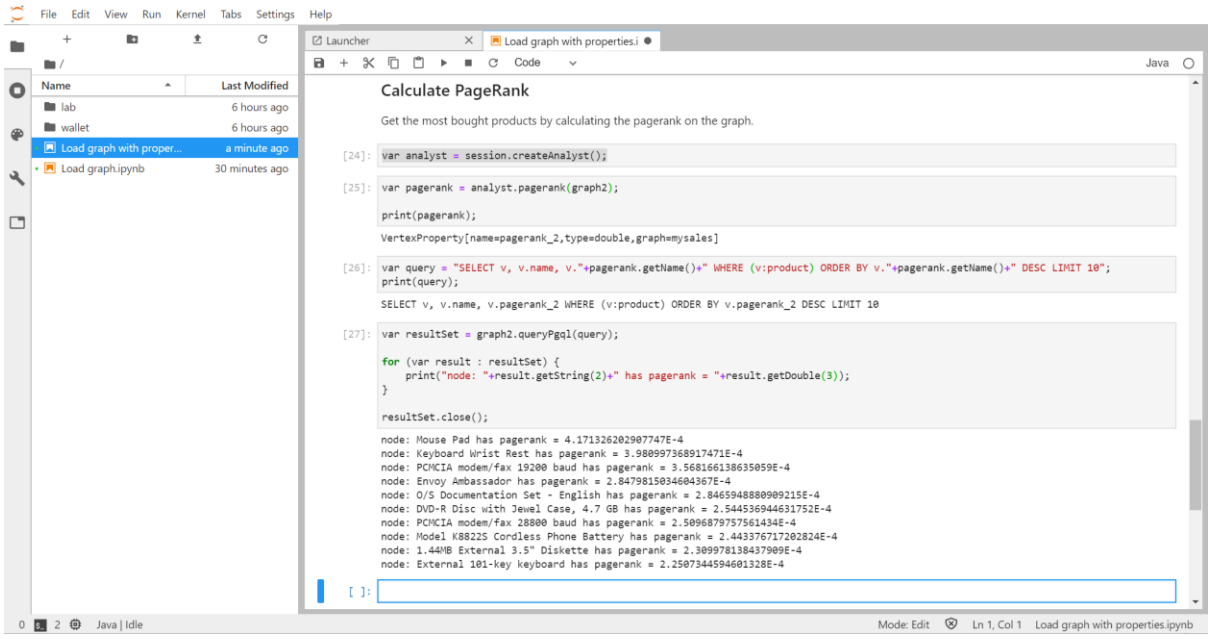
```
for (var result : resultSet) {
    print(result.getString(1) +" bought "+ result.getFloat(5)
          +" "+ result.getString(2) +" the "+ result.getDate(3) +"
for "+ result.getFloat(4) +"$");
}

for (var result : resultSet) {
    print(result.getString("c.name") +" bought "+
result.getFloat("b.quantity")
          +" "+ result.getString("p.name") +" the "+
result.getDate("b.orderDate") +" for "+ result.getFloat("b.amount")
+"$");
}
```



The components of each row can be retrieved based on their type (by using getString(…), getFloat(…) etc.) and referenced either using a position reference of the column in the result (starting with 1 for the first one) or by name. If an alias has been used for a column this name must be the alias.

8) Execute an algorithm on the graph

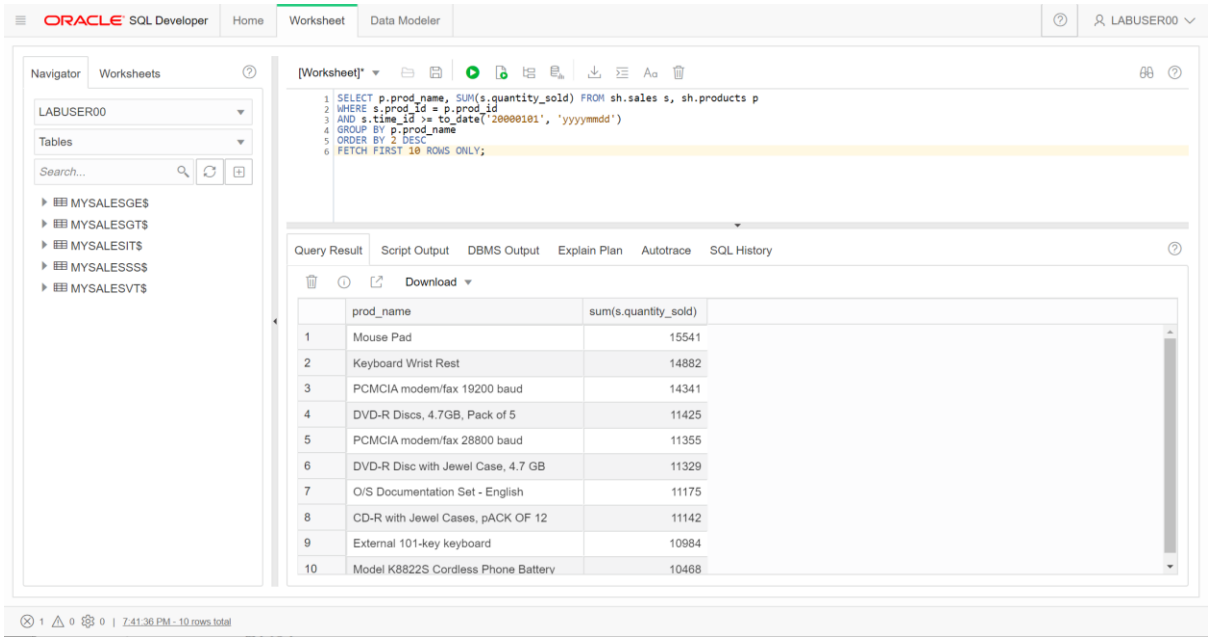
```
var analyst = session.createAnalyst();

var pagerank = analyst.pagerank(graph2);
print(pagerank);

var query = "SELECT v, v.name, v."+pagerank.getName()+" WHERE
(v:product) ORDER BY v."+pagerank.getName()+" DESC LIMIT 10";
print(query);
var resultSet = graph2.queryPgql(query);
for (var result : resultSet) {
    print("node: "+result.getString(2)+" has pagerank =
"+result.getDouble(3));
}
resultSet.close();
```



To execute algorithms, you first need an object "analyst" which can be obtained from the PGX session.

The result of an algorithm is often a property (or a set of properties) which will be used to store the result of the algorithm on the various nodes and/or edges impacted. This result is useful to know the name of the property holding the result.

A "pagerank" calculation across the graph and retrieving the products with the highest pagerank must, intuitively, be close to the list of products with the highest quantity sold.



You can see that the “pagerank” TOP10 calculation on products has many common elements with the TOP10 of the products by quantity sold retrieved by a query in the database.

Slide 56


Graph Visualization, Cytoscape, custom visualizations, REST interface,
PGQL to SQL translation, ML
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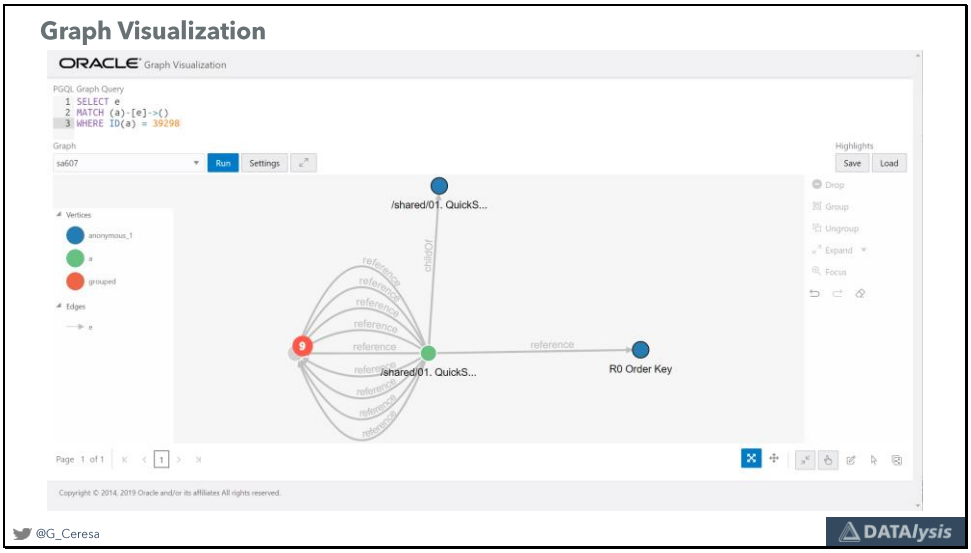
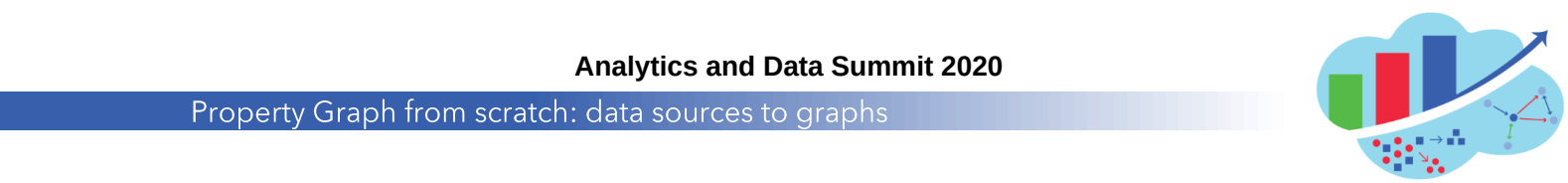
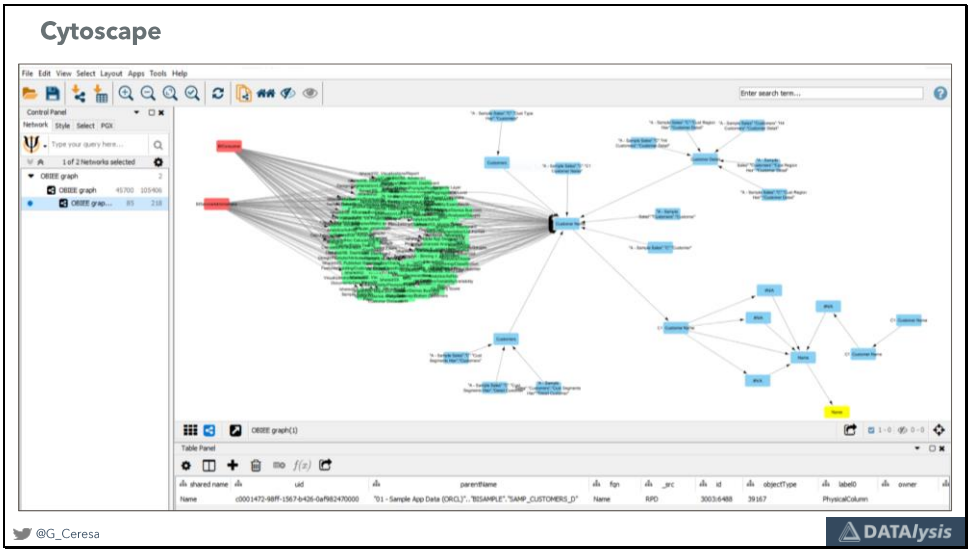
Slide 57



If you use Graph server 20.1.0 standalone it will by default allow you to access Graph Visualization. A web interface in which you can enter a PGQL query and navigate from there through the results.

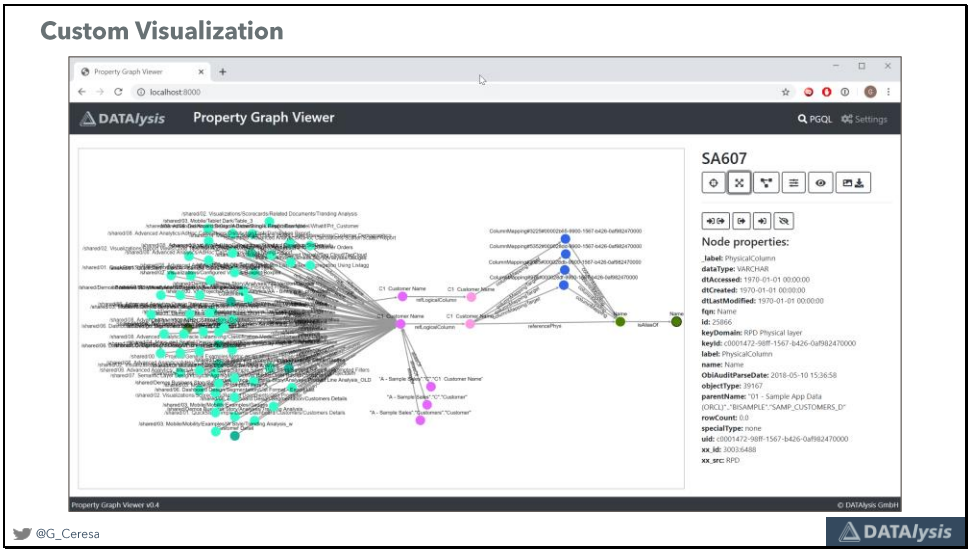


Slide 58

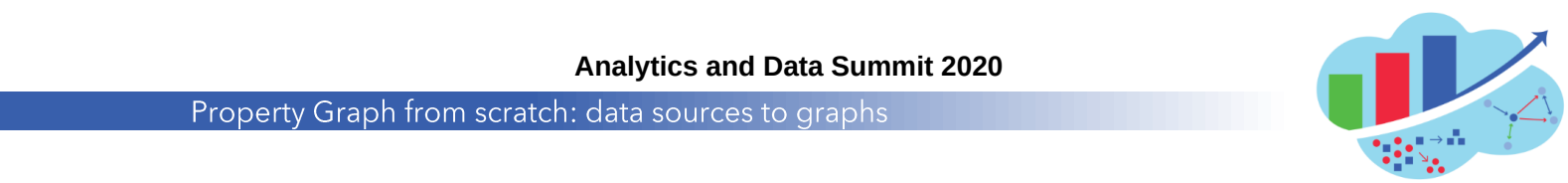


Another visual alternative is using Cytoscape. An open source application you can install and for which Oracle provides a plugin to add support for PGX with graphs stored in the database.

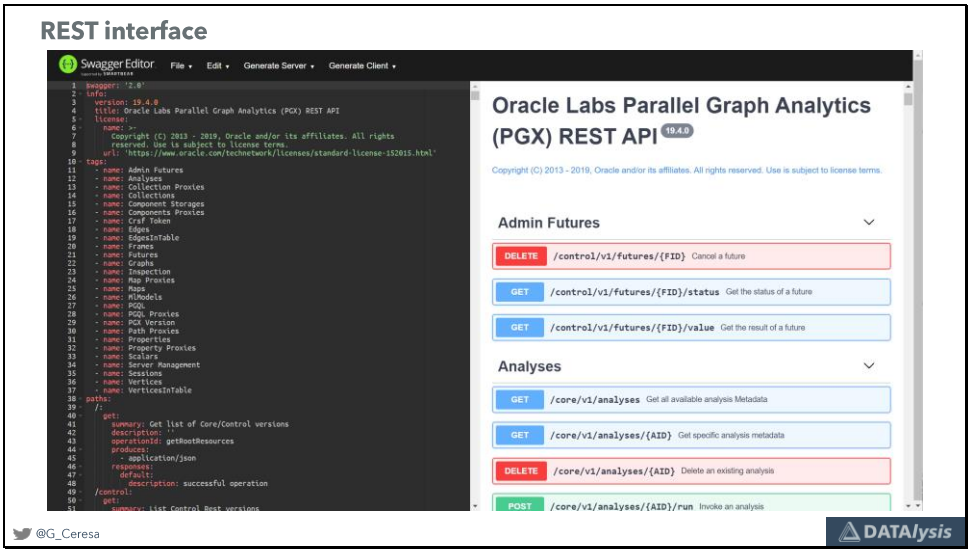
Slide 59



Thanks to the REST web service you can also develop your own visualization tool or integration. Using various libraries like for example CytoscapeJS to easily visualize and interact with a graph in a web application.



Slide 60



The REST web service is fully documented, a swagger.json file is provided.

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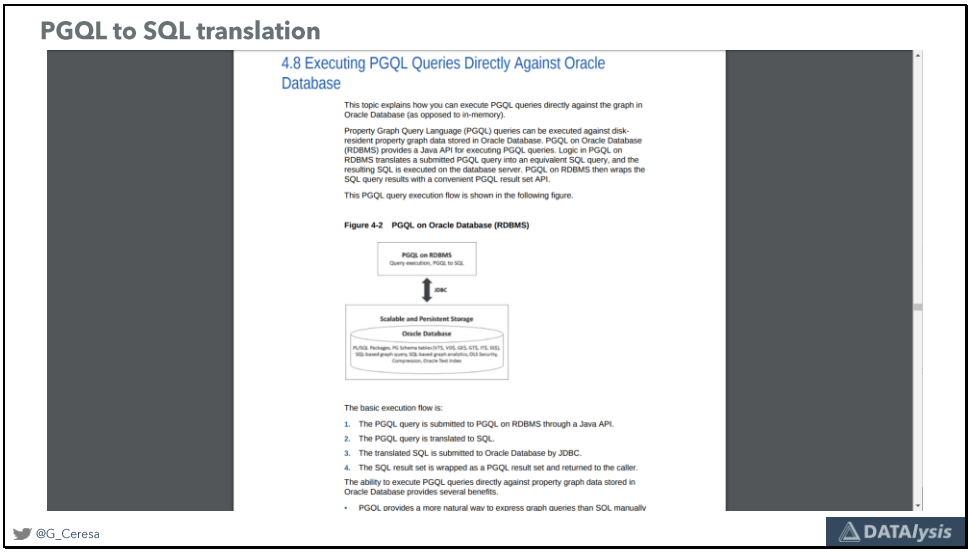

If you want to translate a PGQL query into SQL to execute it directly in the database bypassing PGX (which means you don't have to load the graph into PGX but you can use directly in the database), you can find the details in the documentation.

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Machine Learning

On top of the graph algorithms, which are a kind of machine learning already, there is also "real" machine learning which is possible with Oracle Property Graphs.

You can find out more by having a look at this talk I did on the topic:
https://speakerdeck.com/gianniceresa/when-machine-learning-meets-graph-databases-6eebb419-fa32-4e7e-af03-aafaf601f759

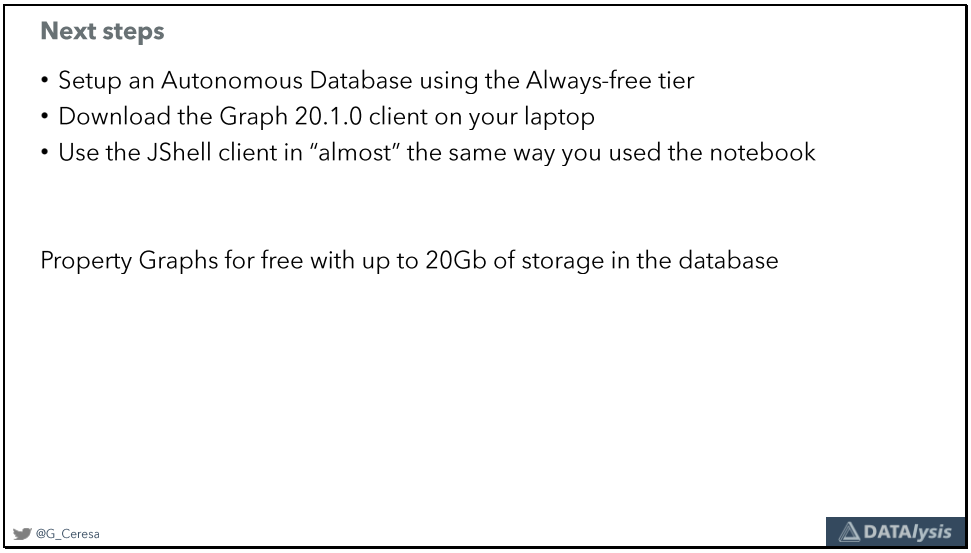
Right now this part isn't available in the Graph Server 20.1.0, it was a beta feature in the Oracle Labs release of PGX. It's supposed to be available in the product later this year.
(I have no influence on Oracle plans and strategy, therefore things could still change)

@G_Ceresa DATAlysis

Machine Learning is already possible with graphs, and more advanced algorithms are supposed to be available in the product soon.

Slide 63

Slide 64



You can easily get started practicing and experimenting Oracle property graph by using the Always-free tier in the Oracle cloud. Create an account and setup your Autonomous Data warehouse instance. Create your graphs there and use the PGX client from your own laptop to directly connect to that database and perform queries or algorithms on the graph.