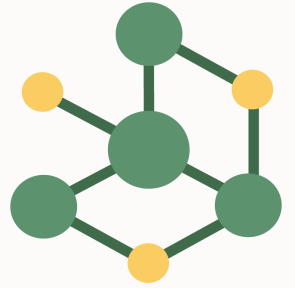


ORACLE

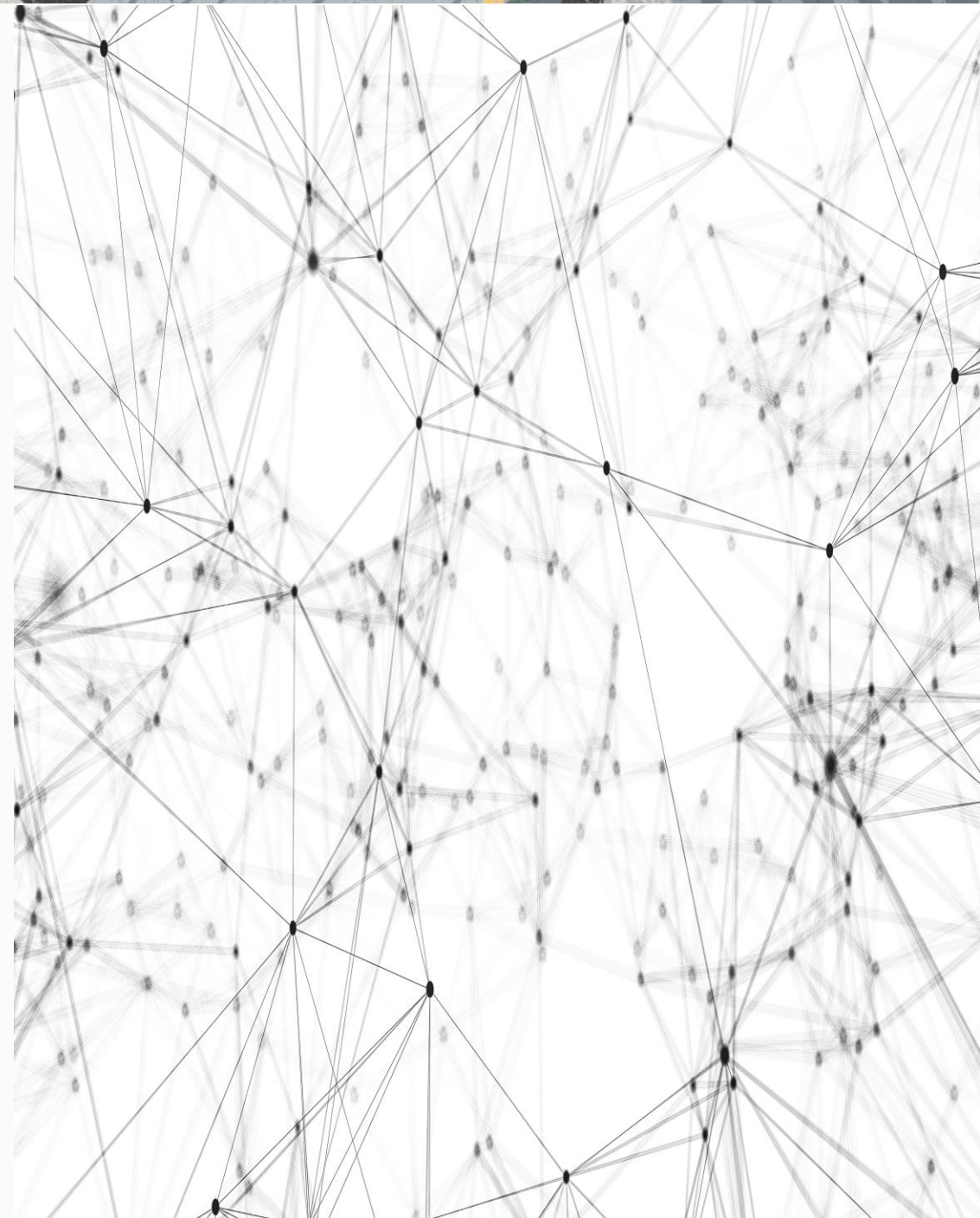


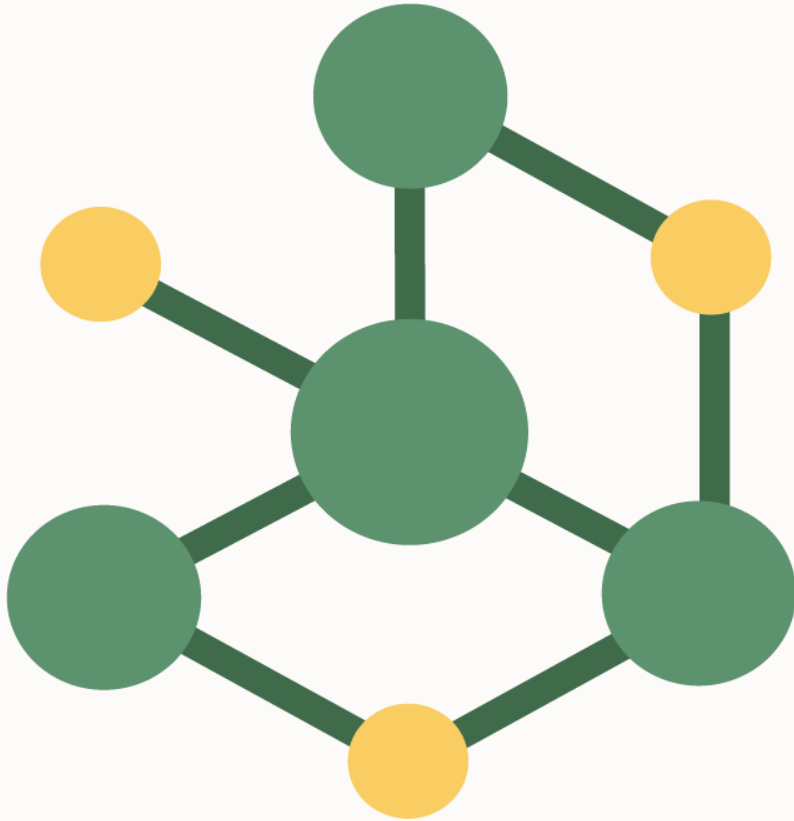
Property Graph

Build Data-Driven Apps, Visualize Relationships, Generate Instant Data Insights

Safe harbor statement

The following is intended to outline our general product direction. It is intended for information purposes only, and may not be incorporated into any contract. It is not a commitment to deliver any material, code, or functionality, and should not be relied upon in making purchasing decisions. The development, release, timing, and pricing of any features or functionality described for Oracle's products may change and remains at the sole discretion of Oracle Corporation.





Agenda

- What is Property Graph?
- Graph Data Model, Graph Query, & Graph Analytics, History, Use Cases
- Oracle Graph vs. Native Graph Databases
- Oracle Graph with Autonomous Database
- Customer References
- What's Next?
- Q&A



What is Property Graph?

DEFINITION

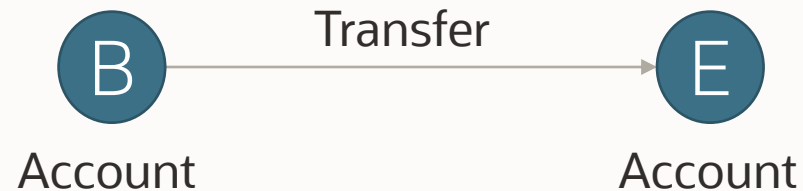
“A property graph is a type of graph model that represents entities (nodes) and their relationships (edges), while also allowing the attachment of properties or attributes to both nodes and edges, enabling rich and flexible data modeling and analysis.”

What does a Property Graph do?

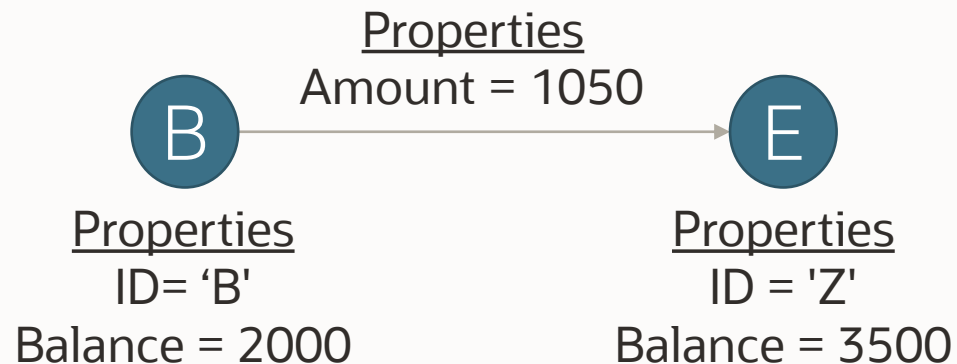
- Model data based on relationships in a natural and intuitive way
- Discover connections and patterns in data visually and fast
- Use embedded graph algorithms for instant results without dependency on developers

Simple Graphs

When navigating multi-hop connections between entities, it is simpler to think of connections as a graph, for example, in case of a banking system, with accounts being vertices and the transfers being edges:



The vertices and edges of a graph can each have properties (columns values)

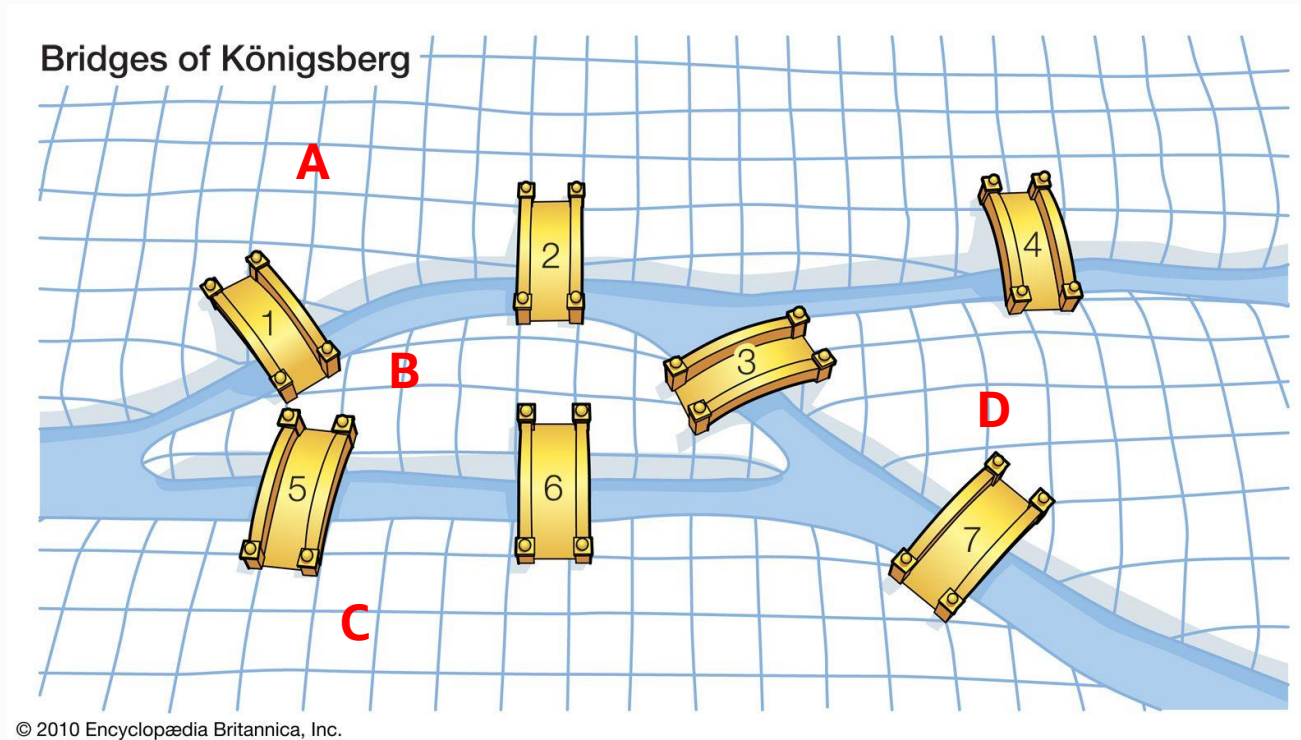


Graph Theory

Euler's 7 Bridges

CHALLENGE

Determine if it was possible to walk through the city, crossing each bridge exactly once, and return to the starting point



Nodes & Degrees

A (3)
B (5)
C (3)
D (3)

Edges

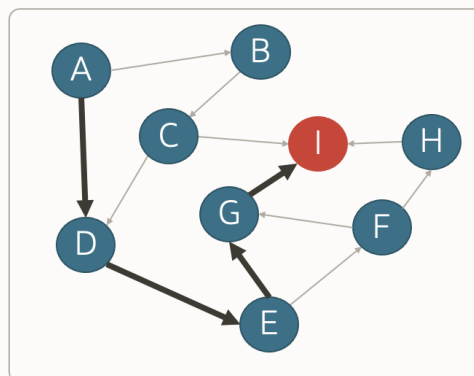
A \leftrightarrow B – 1
A \leftrightarrow B – 2
A \leftrightarrow D – 4
B \leftrightarrow C – 5
B \leftrightarrow C – 6
B \leftrightarrow D – 3
C \leftrightarrow D – 7

Remove Bridges 6 and 4 – PATH (A \rightarrow 1 \rightarrow 5 \rightarrow 7 \rightarrow 3 \rightarrow 2 \rightarrow A)

Tracing Connections in Data

| ID | DEPENDS_ON |
|----|------------|
| A | B |
| A | D |
| B | C |
| C | I |
| C | D |
| D | E |
| E | F |
| E | G |
| F | G |
| F | H |
| G | I |
| H | I |

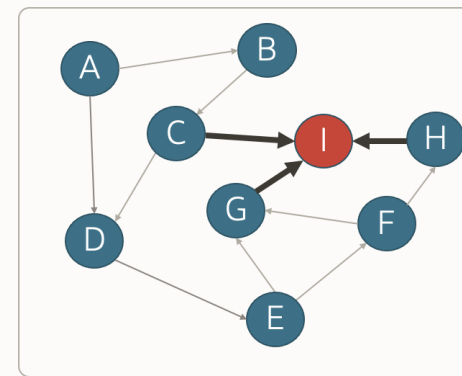
Question:
Is A connected to I?



Is A connected to I?

Graphs make it easier to answer such queries

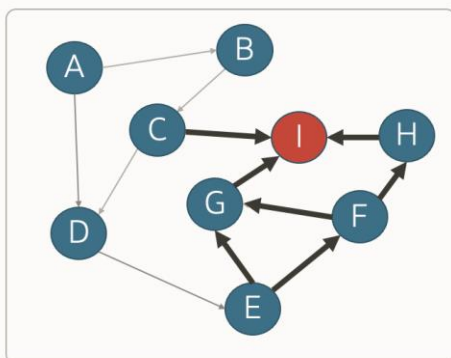
Operate on data as nodes (a.k.a vertices) and edges, instead of as rows and columns



Now, some other queries.

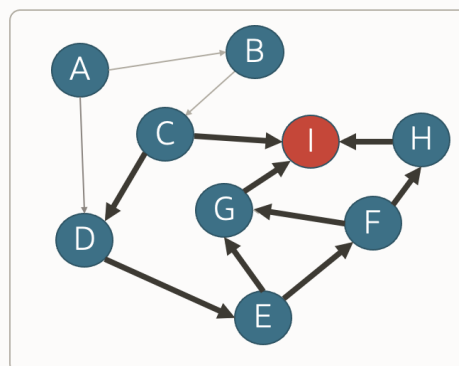
Which nodes are directly connected to node I?
(1 hop long)

Graph pattern syntax in SQL/PGQ
`(<src>) - [] -> (I)`



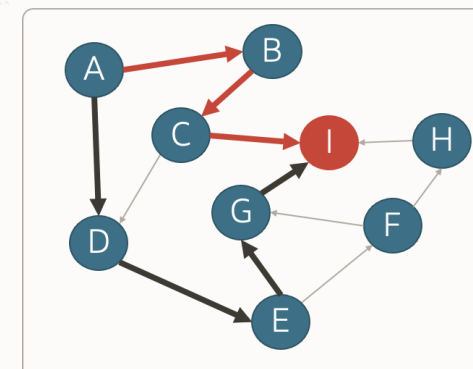
Which nodes are connected to node I in 1 or 2 hops?

Graph pattern syntax in SQL/PGQ
`(<src>) - [] -> {1,2} (I)`



More connections to node I: 1, 2 or 3 hops long

Graph pattern syntax in SQL/PGQ
`(<src>) - [] -> {1,3} (I)`



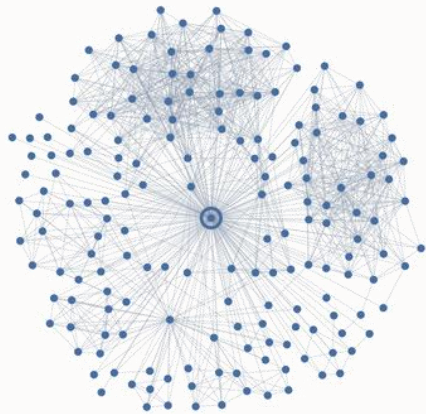
Multiple paths: What are all the paths between node A and node I?

Graph pattern syntax in SQL/PGQ
`(A) - [] ->+ (I)`

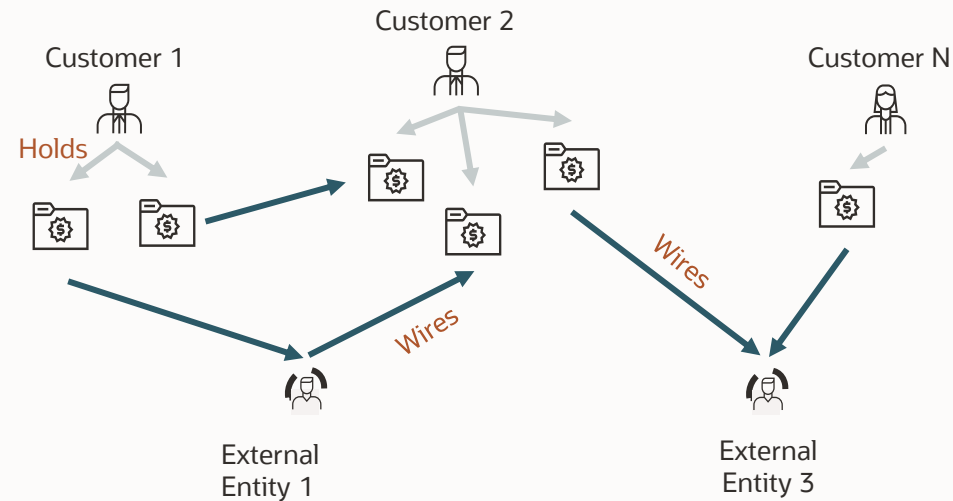


Connections Between Entities are Everywhere

Social networks



Bank Transactions



- ✓ Transportation Networks
- ✓ Supply Chain Networks
- ✓ Interactions between things and between people
- ✓ More...

Graphs make it simple to get value from the information inherent in connections



Solving Business Problems with Graph Query and Graph Analytics

| Business Problem | Solution with Graph Query & Graph Analytics |
|---|---|
| Fraud Detection in Financial Transactions | Identify patterns of suspicious transactions by tracing cycles in cash transfer relationships and identifying accounts with a high volume of transactions. |
| Supply Chain Optimization | Model the relationships and dependencies between suppliers, manufacturers, distributors, and retailers to identify bottlenecks, optimize inventory levels, and improve overall supply chain efficiency. |
| Social Network Analysis and Influencer Marketing | Analyze the connections between individuals, communities, and influencers to identify influential users, target marketing efforts, and understand information diffusion patterns |
| Personalized Recommendations in E-commerce | Analyze customer behavior, preferences, and purchase history to generate personalized recommendations by leveraging connections between customers, products, and their attributes |
| IT Infrastructure Management and Dependency Mapping | Model IT infrastructure components, their relationships, and dependencies to identify impact analysis, plan maintenance, optimize resource allocation, and ensure reliable operations. |
| Customer Journey Analysis | Model touch points and interactions across different channels to understand the customer journey, identify pain points, optimize customer experience, and drive customer loyalty. |
| Risk Assessment and Compliance | Map and analyze relationships between risk factors, compliance requirements, and entities to assess and mitigate risks, ensure regulatory compliance, and identify potential areas of concern. |
| Knowledge Graphs and Semantic Search | Build knowledge graphs to capture semantic relationships between entities, enabling advanced semantic search, contextual recommendations, and knowledge discovery. |
| Healthcare Network Analysis | Analyze patient-doctor relationships, medical records, and treatment outcomes to improve care coordination, identify patterns in disease spread, and optimize healthcare delivery. |
| Asset Management and Predictive Maintenance | Model relationships between assets, maintenance records, and sensor data to optimize asset performance, predict failures, and schedule maintenance proactively. |



Relational Queries

SQL JOINS are great for navigating between entities when there are simple static connections between them

For example, find money transfers from bank account 'B' to 'E'

BANK_ACCOUNTS

| ID | Balance |
|-----|---------|
| A | |
| B | 20000 |
| ... | |
| ... | |
| ... | |
| E | 35000 |

BANK_TRANSFERS

| FROM_ACC | TO_ACC | AMOUNT |
|----------|--------|--------|
| ... | ... | ... |
| B | E | 1050 |
| ... | ... | ... |



```
-- transfers directly from 'B' to 'E'
```

```
SELECT ...  
FROM   bank_accounts fr_acc,  
        bank_accounts to_acc,  
        bank_txn trn  
WHERE  trn.from_acc = fr_acc.id  
AND    trn.to_acc.  = to_acc.id  
AND    fr_acc.id = 'B'  
AND    to_acc.id = 'E';
```

Relational Queries

However, it is very complex to write a SQL JOIN that returns all accounts where some money flowed from account 'B' to account 'E' through up to 2 intermediate accounts

- This would require a SQL statement with 12 joins and 3 unions to handle all combinations of intermediate accounts
- Complexity increases rapidly with more intermediate accounts and more complex queries

```
-- transfers indirectly from 'B' to 'E'

SELECT v1.id as account_id1 , v2.id as account_id2
FROM   bank_accounts v1 ,
       bank_txns btx,
       bank_accounts v2
WHERE  (v1.id = btx.from_acc AND v2.id = btx.to_acc)
AND    v1.id= 'B' AND v2.id= 'E'
UNION ALL
SELECT v1.id as account_id1 , v2.id as account_id2,
FROM   bank_accounts v1 ,
       bank_txns btx,
       bank_accounts bc2,
       bank_txns btx2 ,
       bank_accounts v2
WHERE  (v1.id = btx.from_acc AND bc2.id = btx.to_acc AND
       bc2.id = btx2.from_acc AND v2.id = btx2.to_acc )
AND    v1.id= 'B' AND v2.id= 'E'
UNION ALL
SELECT v1.id as account_id1 ,v2.id as account_id2
FROM   bank_accounts v1 ,
       bank_txns btx,
       bank_accounts bc2,
       bank_txns btx2 ,
       bank_accounts bac4,
       bank_txns btx5 ,
       bank_accounts v2
WHERE  (v1.id = btx.from_acc AND bc2.id = btx.to_acc AND
       bc2.id = btx2.from_acc AND bac4.id = btx2.to_acc AND
       bac4.id = btx5.from_acc AND v2.id = btx5.to_acc )
AND    v1.id= 'B' AND v2.id= 'E'
;
```

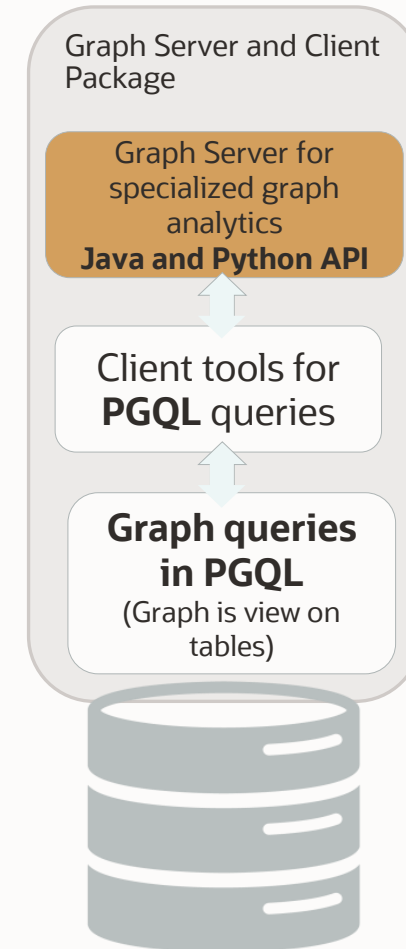
Oracle Database's Graph Capabilities (up to 19c)

Oracle DB 19c already includes (for free) analytic graph queries using an open-source SQL-like graph language called PGQL

Provides parallel in-memory graph analytics with over 60 pre-built graph algorithms

- Community detection, popularity
- Ranking, walking, path finding
- etc.

Super fast analytics – faster than specialized graph databases



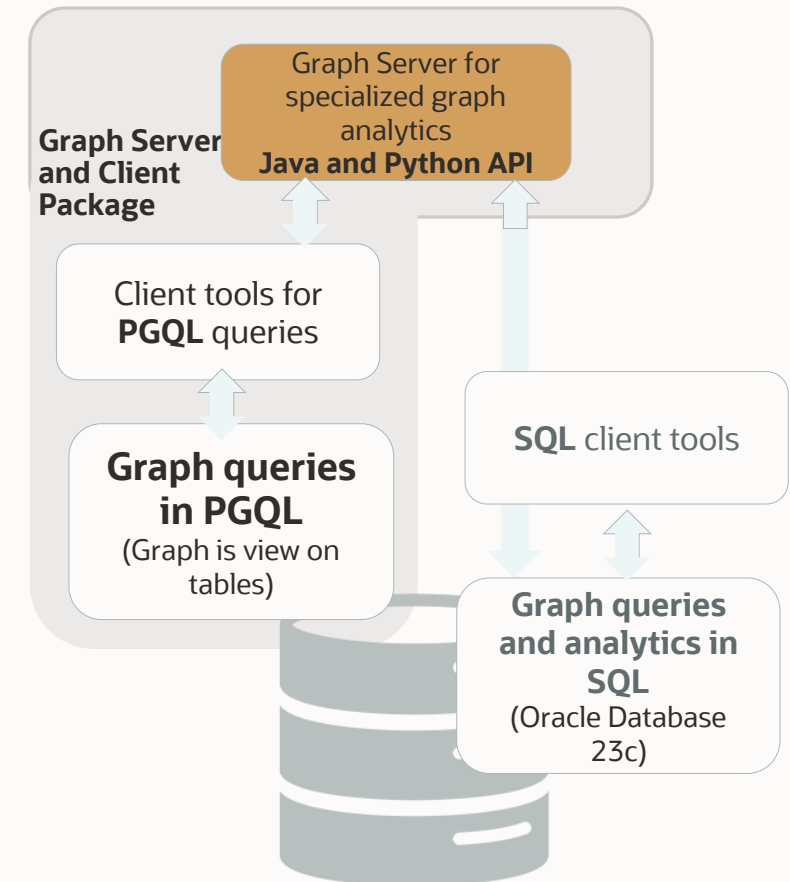
Oracle Database's Graph Capabilities (Oracle Database 23)

Oracle Database 23 natively implements property graph queries using the new ISO Standard SQL Syntax called SQL/PGQ (ISO/IEC 9075-16)

- Seamlessly works with any SQL client, tool, framework

SQL Property Graphs are views defined on top of existing relational or JSON (schema-less) data

- Enables Graph Queries on real-time OLTP data
 - Free feature that eliminates the complexity of creating, maintaining and synchronizing a separate graph database
 - Inherits all high-availability, security, concurrency, flexibility, consistency, OLTP, DW, converged features of Oracle DB
- ✓ **Because of this Oracle Graph SQL is the graph engine for the enterprise**



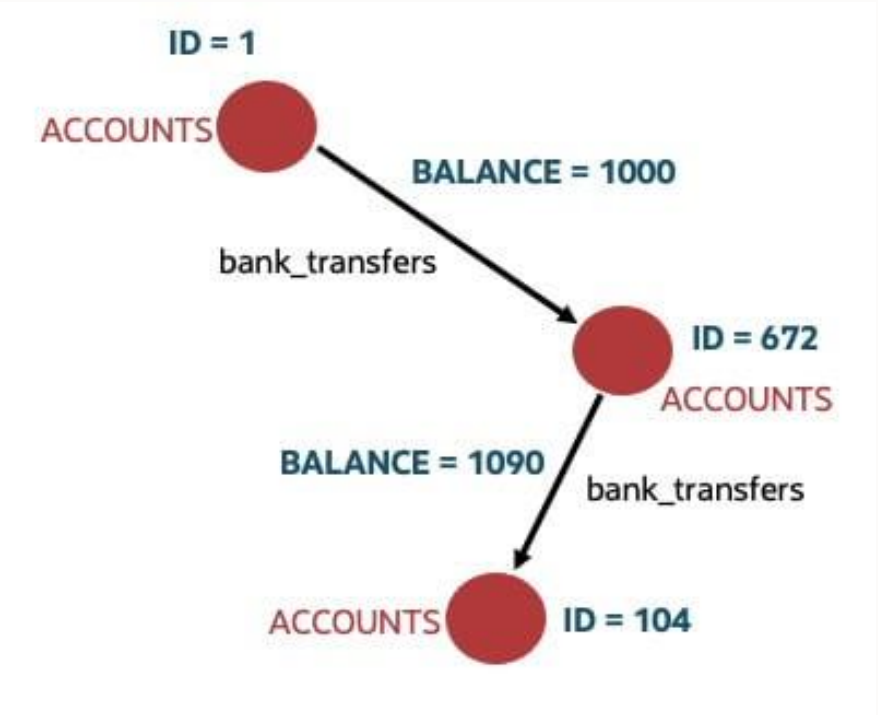
Oracle Property Graph: Additional Features

- Familiar SQL interface for Graph Queries and Graph Analytics
- Supports graph operations, indexing, queries, search, and in-memory analytics
- Fast, scalable suite of data analysis functions that include:
 - Ranking, Centrality, Recommender, Community Detection, and Path Finding
- Graph Visualization App
- Notebook support through Jupyter



Property Graph Data Model

Graph Example Using Bank Accounts

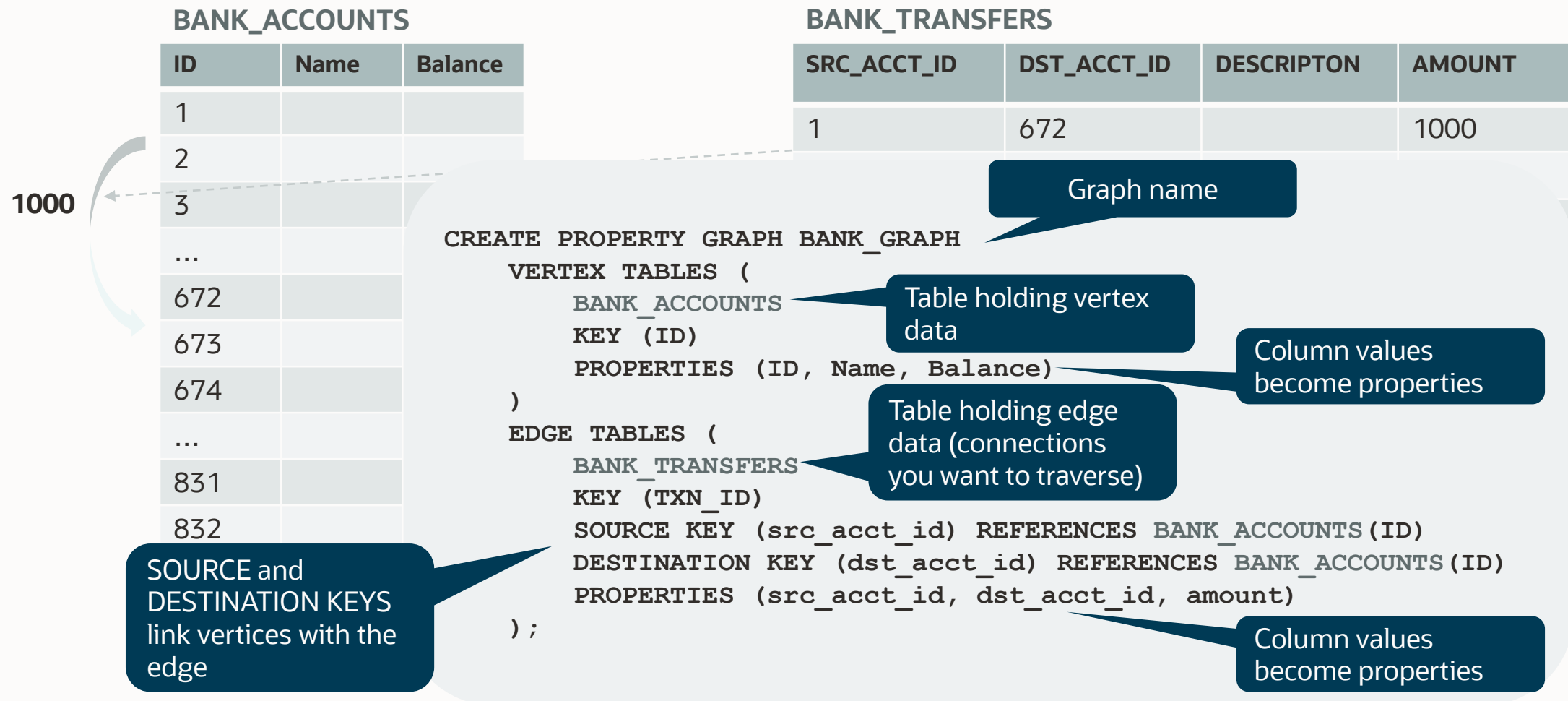


| Symbol | Name | Example |
|--------|---------------|--|
| () | Vertex | (v1) and (v2) are bank accounts |
| [] | Edge | [e1] represents a cash transfer between them |
| {} | <Path Length | {1,3} |
| → | Directed Edge | |

GRAPH QUERY SYNTAX



Creating Property Graph



Querying Graph

/* List accounts which have transferred money to another account */

```
select account_id from GRAPH_TABLE (bank_graph  
  MATCH (src)-[is bank_transfers]->(dst)  
  COLUMNS (src.id as account_id) );
```

Vertices are in (), edges are in []

Columns to return

/* List accounts which have transferred money through intermediate accounts */

```
select account_id from GRAPH_TABLE (bank_graph  
  MATCH (src)-[is bank_transfers]->{1,3}(dst)  
  COLUMNS (src.id as account_id) );
```

Path length in {} – from 1 to 3 hops

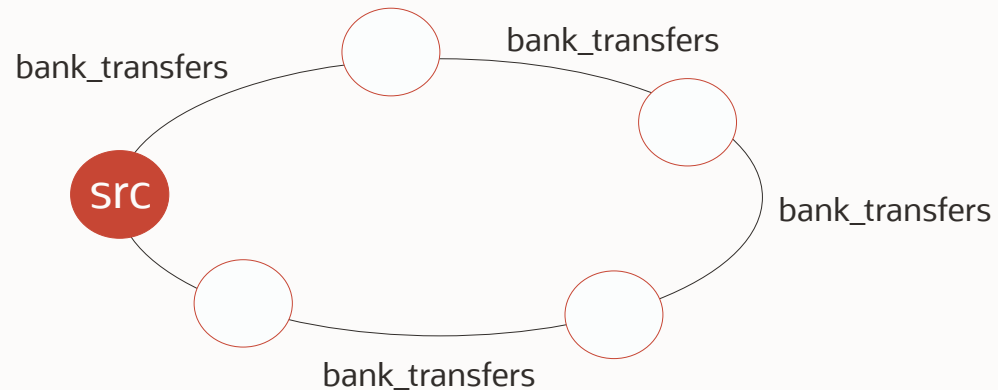


Querying Graph

/* List accounts which have 5 hop transfers that start and end with the same account, and order by number of such cycles*/

```
SELECT acct_id, COUNT(1) AS Num_5hop_Chains
FROM graph_table (BANK_GRAPH
  MATCH (src) - []->{5} (src)
  COLUMNS (src.id AS acct_id)
) GROUP BY acct_id ORDER BY Num_5hop_Chains DESC;
```

Starting vertex and ending vertex are the same



Using SQL*Developer to Create a SQL Property Graph

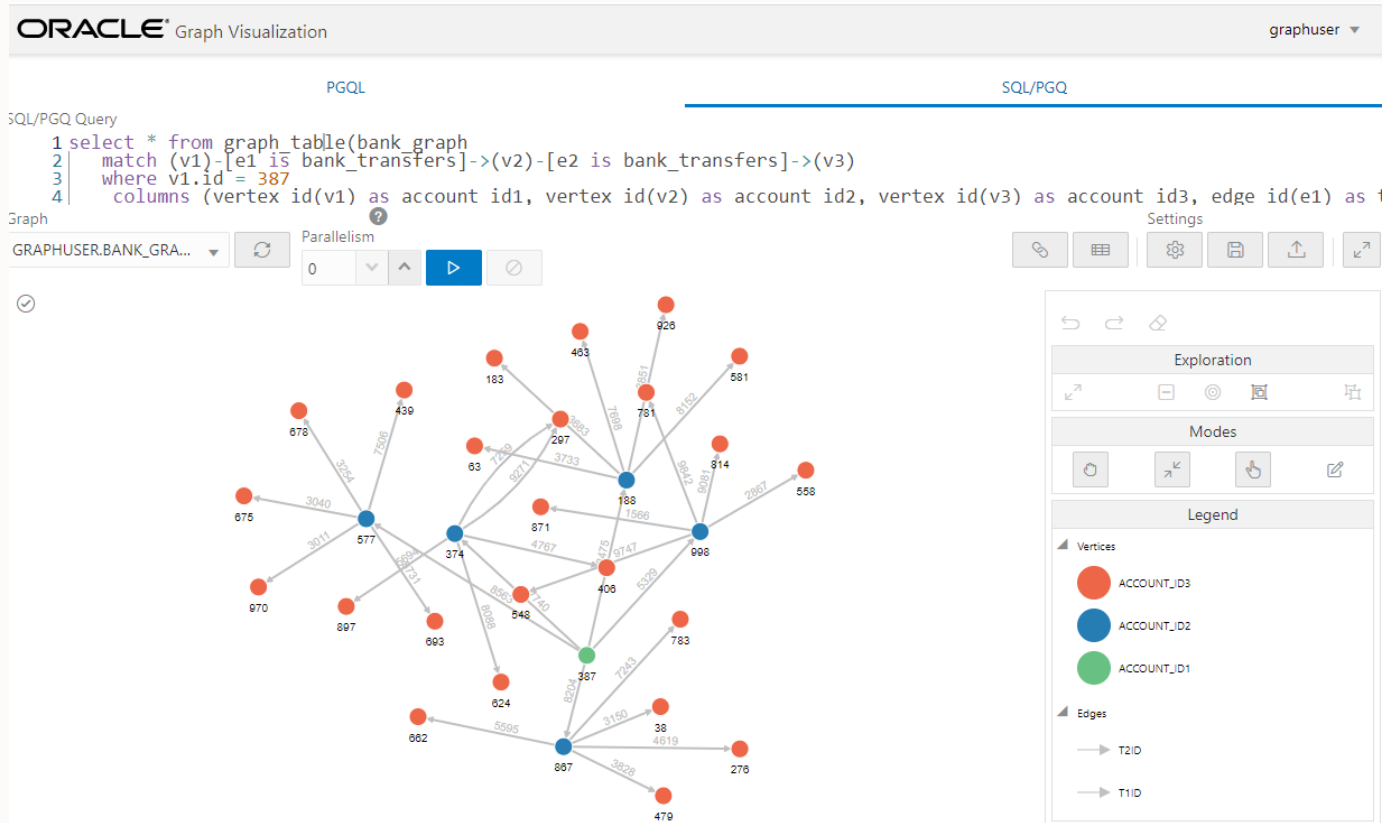
The screenshot displays the SQL*Developer interface. On the left, the 'Oracle Connections' tree shows a connection named 'ade'. Below it, the 'Reports' tree is visible. The main workspace is divided into two panes: 'Worksheet' and 'Query Builder'. The 'Query Builder' pane shows the SQL statement for creating a property graph named 'students_graph'. The statement defines vertex tables for 'persons', 'friendships', 'university', and 'students', and an edge table for 'friendships'. The 'Script Output' pane at the bottom shows the message 'Property GRAPH created.' and the execution time 'Task completed in 0.334 seconds'.

```
CREATE PROPERTY GRAPH students_graph
  VERTEX TABLES (
    persons
      KEY (person_id)
      LABEL person
      PROPERTIES (person_id, name, birthdate AS dob)
      LABEL person_ht
      PROPERTIES (height),
    friendships
      LABEL friend_of
      NO PROPERTIES
      LABEL all_friends
      PROPERTIES ARE ALL COLUMNS EXCEPT (person_a, person_b),
    university
      KEY (id),
    students AS student
      PROPERTIES ARE ALL COLUMNS EXCEPT (height)
  )
  EDGE TABLES (
    friendships AS friends
      KEY (friendship id)
```

Property GRAPH created.

Visualizing Graph Query Results

A powerful stand-alone Graph Visualization application

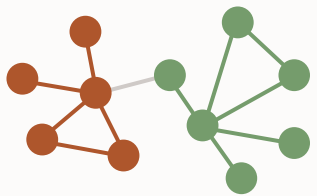


- A single-page web application that works with the graph server (PGX)
- Select PGQL driver at the time of logging in, to connect to the database or to the PGX
- Can only visualize graphs which are already loaded into PGX or Oracle Database



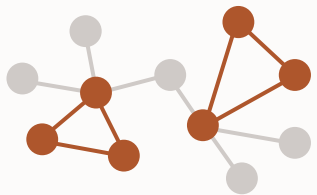
Graph Analytics

60+ parallelized, in-memory algorithms out-of-the-box



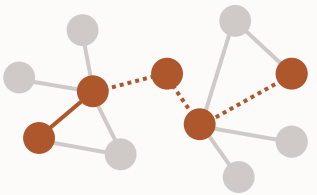
Detecting communities

Strongly Connected Components, Weakly Connected Components, Label Propagation, Louvain, Conductance Minimization, Infomap



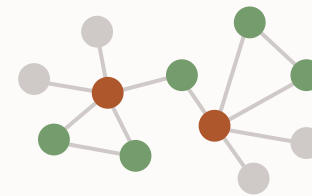
Topology analysis

Conductance, Cycle Detection, Degree Distribution, Eccentricity, K-Core, LCC, Modularity, Reachability Topological Ordering, Triangle Counting, Bipartite Check, Partition conductance



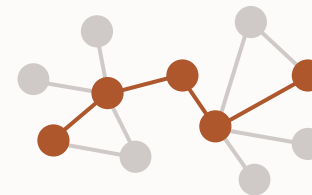
Link prediction and others

Twitter Whom-to-follow, SALSA, Adamic-Adar Index



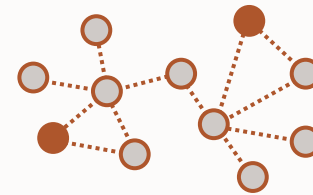
Ranking and walking

PageRank, Personalized PageRank, Degree Centrality, Closeness Centrality, Vertex Betweenness Centrality, Eigenvector Centrality, HITS, Minimum Spanning-Tree (Prim's), Breadth-First Search, Depth-First Search, Random Walk with Restart



Path-finding

Shortest Path (Bellman-Ford, Dijkstra, Bidirectional Dijkstra), Fattest Path, Compute Distance Index, Enumerate Simple Paths, Filtered and Unfiltered Fast Path Finding, Hop Distance



Machine learning

DeepWalk, Supervised GraphWise, Unsupervised GraphWise, Pg2Vec, Matrix Factorization, GNNExplainer

Oracle Property Graph with Oracle Autonomous Database

- Graph Studio
 - ✓ A fully managed service with a powerful user interface for developing applications that use graph analysis.
 - Automate the modeling of graphs from tables in Autonomous Database
 - Interactively analyze and visualize the graph queries using advanced notebooks with multiple visualization options
 - Execute over 60 built-in graph algorithms in Graph Studio to gain useful insights on your graph data
 - Access few Graph Studio features using the Autonomous Database Graph Client API using the client shell CLIs or through your Java or Python application
- Graph Server
 - ✓ Use any version of Oracle Graph Server and Client with the family of Oracle Autonomous Database to create and work with property graphs
 - Upgrade to the latest version of Graph Server and Client regardless of the version of your Autonomous Database. Note that the graph server is managed by the application in this case.
 - Connect
 - ✓ In two-tier mode, connect directly to Autonomous Database
 - ✓ In three-tier mode, connect to PGX on the middle tier, which then connects to Autonomous Database.



Graph Studio

ORACLE Cloud

Search resources, services, documentation, and Marketplace

Germany Central (Frankfurt)

OverviewAutonomous DatabaseAutonomous Database details

ADW

AVAILABLE

RDBPrimary

Database actionsDatabase connectionPerformance hubManage scalingMore actions

Autonomous Database information

Tool configurationTags

General information

Database name: RDB

Workload type: Data Warehouse

Compartment: oraclepartnersas (root)/Team/RSCHARMA

OCID: ...fmeakaShowCopy

Created: Tue, Jul 6, 2021, 20:48:09 UTC

License type: Bring your own license (BYOL), Enterprise Edition

Database version: 19c

Lifecycle state: AvailableCheck database availability

Instance type: Paid

Auto start/stop schedule: Mon, FriEdit

Infrastructure

Dedicated infrastructure: No

Disaster recovery ⓘ

Role: PrimarySwitchover

Backup

Total long-term backup storage: -

Last automatic backup: Wed, May 31, 2023, 05:42:14 UTC

Next long-term backup: -

ORACLE Database Actions | Launchpad

Development

SQL

Execute queries and scripts, browse and manage your...

REST

An IDE for your REST APIs that enables you to manage...

JSON

Create collections, upload documents, query and filter you...

SCHEDULING

An interface for DBMS_SCHEDULER that enable...

APEX

Login to APEX, develop and run rich, low-code web applications.

DATA MODELER

Reverse-engineer schemas to relational diagrams and data...

LIQUIBASE

View ChangeLogs applied to your schema.

CHARTS

Use SQL queries to build rich charts and dashboards containi...

ORACLE MACHINE LEARNING

Oracle Machine Learning provides several components accessible...

GRAPH STUDIO

Graph Studio automates the creation of knowledge (RDF) an...

Data Studio

DATA STUDIO OVERVIEW

Data Studio Tools

DATA LOAD

Load or access data from local files or remote databases.

CATALOG

Understand data dependencies and the impact of changes.

DATA INSIGHTS

Discover anomalies, outliers and hidden patterns in your data.

DATA TRANSFORMS

Transform data for analysis and other applications.

DATA ANALYSIS

Analyze your data.

Graph Studio

Welcome to Oracle Graph

Get Started

Model your existing data as a graph, then create a Notebook to analyze, visualize, and query your graphs by using our 60+ built-in algorithms and PGQL query language.

Model

Model your data as a graph

Start Modeling

Develop and Share

Create and share interactive analyses and visualizations

Notebooks

Discover and share insights with interactive notebooks

Show All

NOTEBOOK

Getting Started(Using the built-in notebooks

Created 7 months ago

NOTEBOOK

Getting Started(Intro to PGQL using the SH property graph

Created 7 months ago

NOTEBOOK

Use Cases/Graph Queries on the SH sample data

Created 7 months ago

NOTEBOOK

Use Cases/Meetup Recommendation

Created 7 months ago

NOTEBOOK

Getting Started(SPARQL Introduction

Created a year ago

Graph Studio

Welcome to Oracle Graph

Get Started

Model your existing data as a graph, then create a Notebook to analyze, visualize, and query your graphs by using our 60+ built-in algorithms and PGQL query language.

Model

Model your data as a graph

Start Modeling

Develop and Share

Create and share interactive analyses and visualizations

Models

Discover and share insights with interactive notebooks

Show All

MODEL

PROGMODEL1

Updated 27 minutes ago by ADMIN

MODEL

SHCUSTOMER1

Updated 43 minutes ago by ADMIN

Graphs

Discover and share insights with interactive notebooks

Show All

GRAPH

PROGGRAPH1

Created 30 minutes ago by ADMIN

GRAPH

SHCUSTOMERGRAPH1

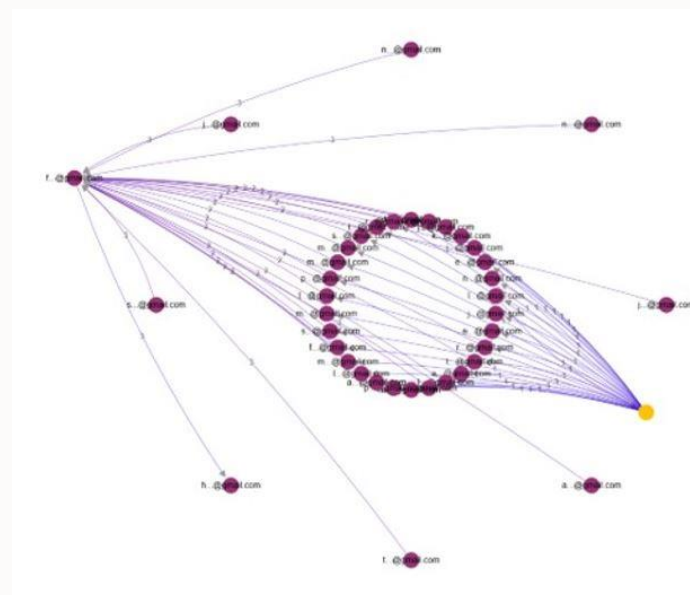
Created 43 minutes ago by ADMIN



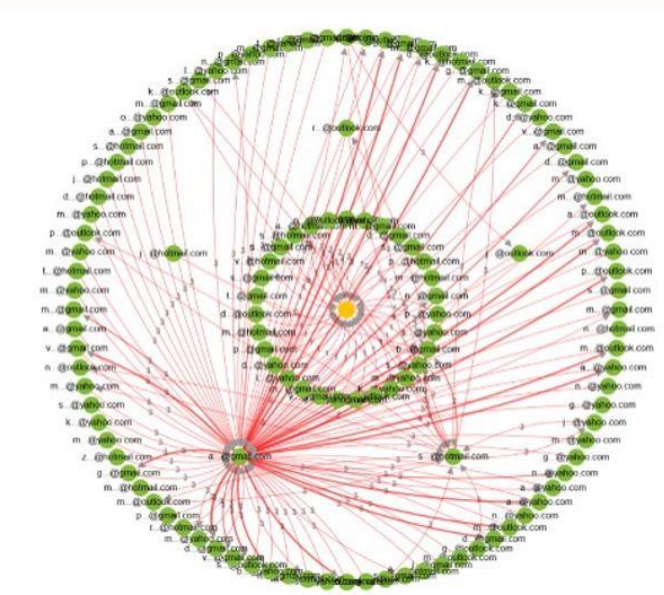
Paysafe: Money Transfer Fraud Detection

Online payment solutions

- Real-time payments, e-wallets
- 1 bn revenue/year
- 500,000 payments/day



Multiple paths going to the same destination



Limited number of source and destination vertices



CaixaBank: Identify Similar Customers

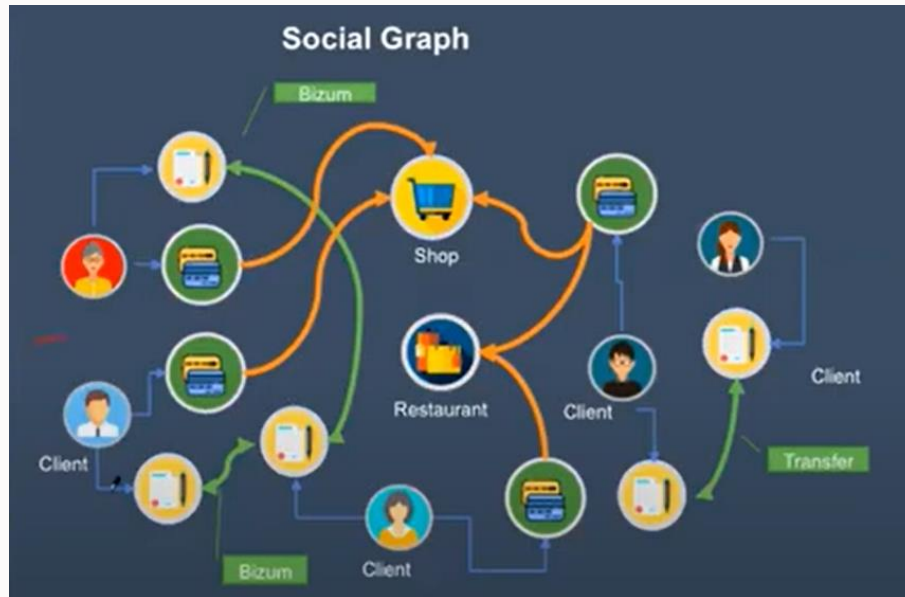
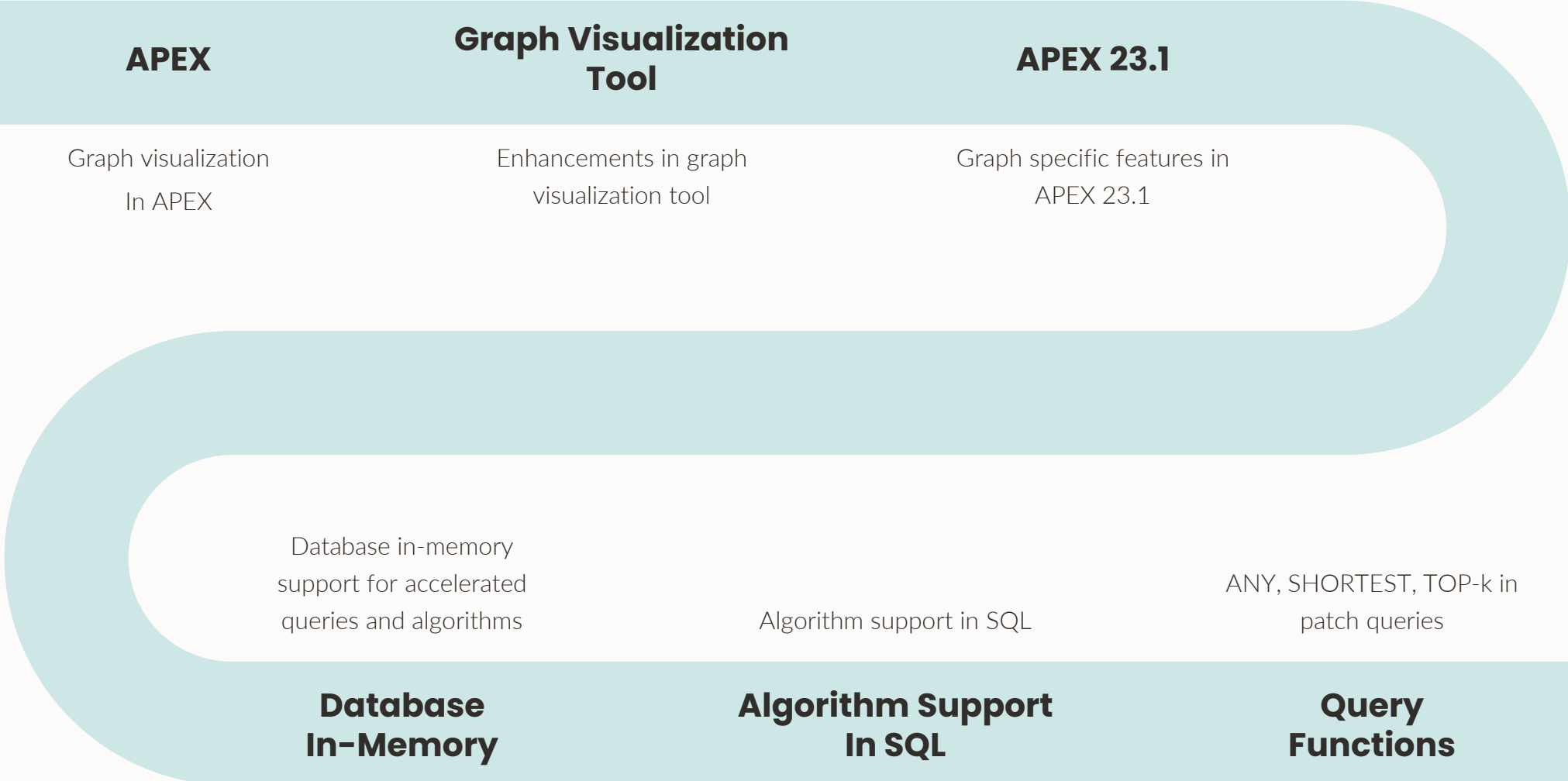


Image courtesy Caixa Bank

- Find communities by analyzing social relationships among CaixaBank customers
- Credit card payments at the “same time/place”
- Money transfer for a social activity (gifts, events, trips, family, etc.)
- Communities have similar interests, similar incomes, would like to buy similar products
- Application used by data scientists, business analysts

- ✓ Large graph: 400 million vertices and 2 billion edges
- ✓ Less than 30ms graph analysis (multi-hop paths) for real-time transaction monitoring

Property Graph: 23c GA and Release Updates



Oracle Property Graph

✓ New in Oracle Database 23

- Native implementation for simplicity and high-performance
- First commercial implementation of PGQ language support in a database
 - Simplifies development and analytics

✓ Oracle Graph is the graph database for the enterprise!

- Enterprise grade features (high-availability, scalability, security, and more)
- No additional cost

✓ No overhead related to moving data around (benefit of Oracle's converged product model)

- Use Oracle Graph today, as easy as issuing a DDL and a DML statement
- Comprehensive support for graph query and analytics (use from SQL, Java, Python, etc)
- Use Graph Studio with Autonomous Database (auto-modeling, self-service tool)

LiveLabs

Learn All About Oracle Graph

- Exploring Operational Property Graphs in 23c Free

<https://apexapps.oracle.com/pls/apex/r/dbpm/livelabs/view-workshop?wid=3659>

- Analyze, Query and Visualize Graphs in Oracle Database

<https://apexapps.oracle.com/pls/apex/r/dbpm/livelabs/view-workshop?wid=686>

- Get started with Graph Studio on Oracle Autonomous Database

<https://apexapps.oracle.com/pls/apex/r/dbpm/livelabs/view-workshop?wid=758>



Connect & Learn More

Take advantage of and benefit from Oracle Graph

- Customers love it that this valuable feature is available with no extra licensing cost
- Available from 12.2 onward, with SQL support in 23c
- Industry use cases: <https://www.oracle.com/database/graph>

RESOURCES



[oracle.com/database/graph/](https://www.oracle.com/database/graph/)



bit.ly/GraphLiveLabs



bit.ly/Spatial-Graph-YouTube



bit.ly/OracleGraphBlog



medium.com/tag/oracle-graph/latest

Specific pointers to some resources

- **Manufacturing:**
<https://medium.com/oracled devs/d65521510975>
- **Financial services**
 - Fraud detection: <https://youtu.be/rggYtCAeGUY>
 - Customer 360: https://youtu.be/j_RIUmd6qps
- **Security (Intrusion detection):**
<https://medium.com/oracled devs/graphs-and-machine-learning-for-cybersecurity-7115b9b544b5>