ORACLE

Graph Algorithms: The Core of Graph Analytics

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August 27, 2020

AskTOM Office Hours: Graph Database and Analytics

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  We're back with new product updates, use cases, demos and technical tips
  https://asktom.oracle.com/pls/apex/asktom.search?oh=3084
- Sessions will be held about once a month
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Agenda

1. Introduction to Graph Algorithms — Melli
2. Graph Algorithms Use Cases — Melli
3. Running Graph Algorithms — Ryota
4. Scalability in Graph Analytics — Ryota

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Recap: Creating a Graph and Querying a Graph

Product Overview: Graph Database and Analytics

Graph data model: A different way to model your data

Property Graph Feature in Oracle Database:

Enterprise capabilities

Highly scalable

- In-memory query and analytics and in-database query
- 10s of billions of edges and vertices

PGQL: Powerful SQL-like graph query language

Analytics Java API: 50+ pre-built graph analysis algorithms

Visualization

- Light-weight web application, UI accessible from a browser

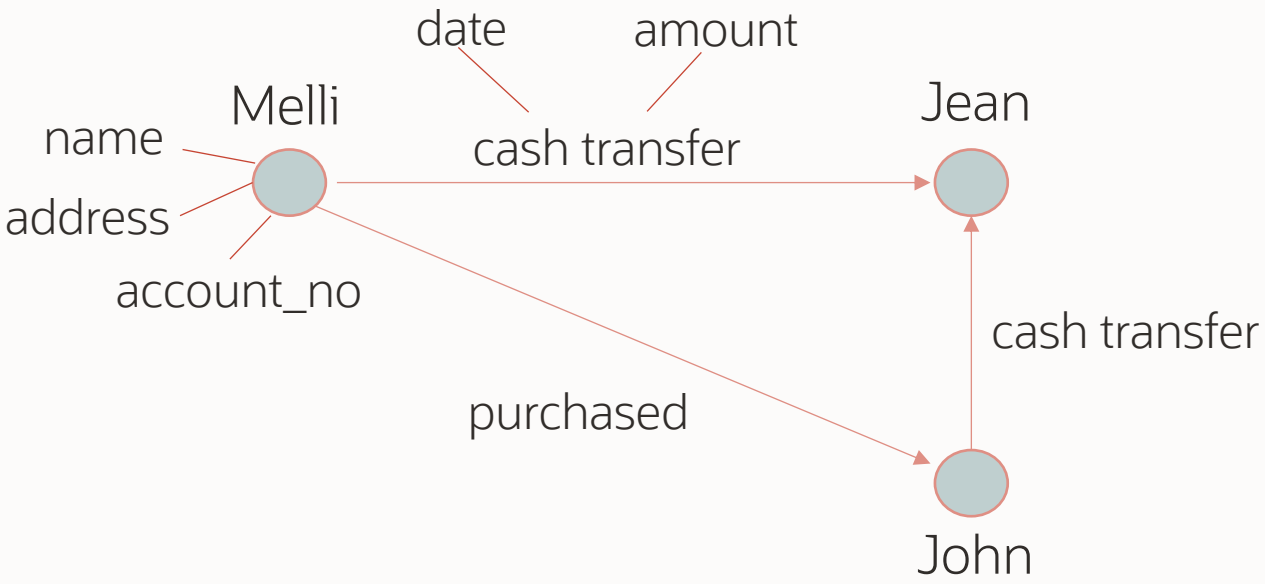
Graph Applications:

- Financial
- Law enforcement and security
- Manufacturing
- Public sector
- Pharma

and more

What is a Graph?

A collection of points (vertices/nodes) and lines between those points (edges)



Create a Graph from Database Tables

ACCOUNTS

ACCT_ID
0
1
2
3
4
5
…

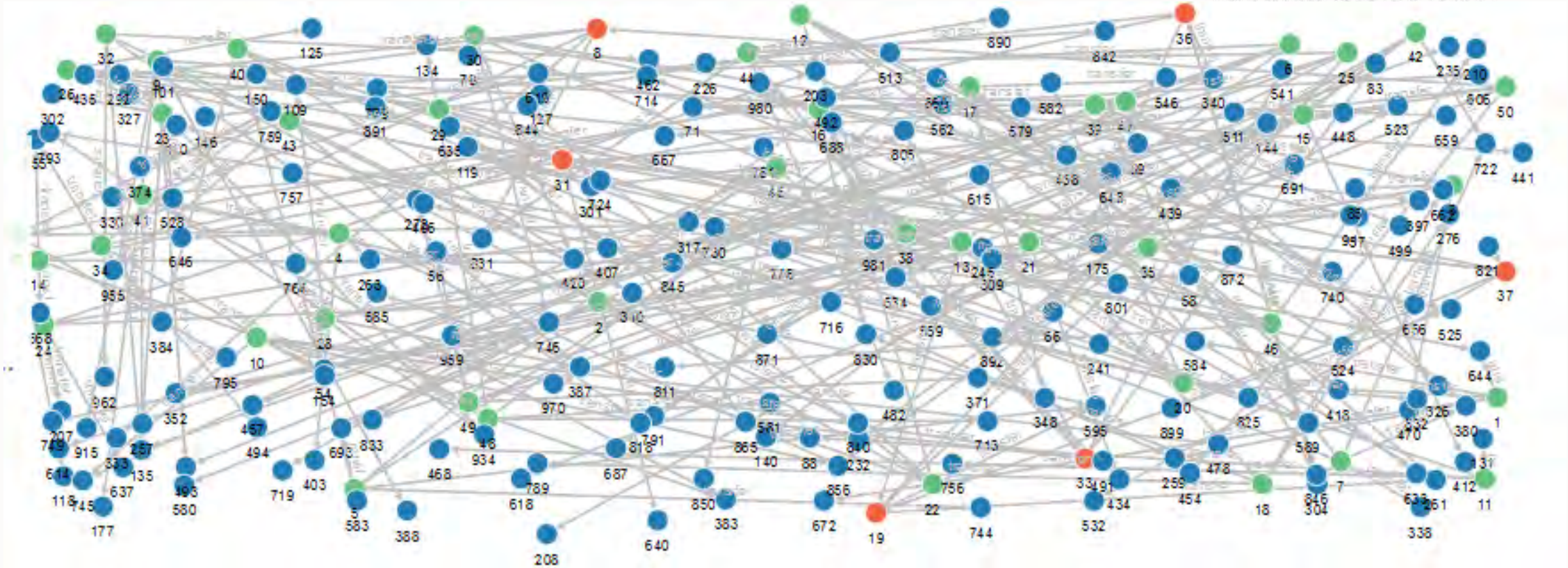
TRANSACTIONS

FROM_ACCOUNT	TO_ACCOUNT	AMOUNT
1	672	1000
1	584	1000
1	259	100000
2	833	5001
2	840	7050
2	493	4363
…	…	…

PGQL DDL SYNTAX:

```
CREATE PROPERTY GRAPH bank_graph
  VERTEX TABLES (
    ACCOUNTS LABEL Account PROPERTIES ( ACCT_ID )
  )
  EDGE TABLES (
    TRANSACTIONS
      SOURCE KEY ( FROM_ACCOUNT ) REFERENCES ACCOUNTS
      DESTINATION KEY ( TO_ACCOUNT ) REFERENCES ACCOUNTS
      LABEL transfer PROPERTIES ( AMOUNT )
```

Cash Transfer Graph

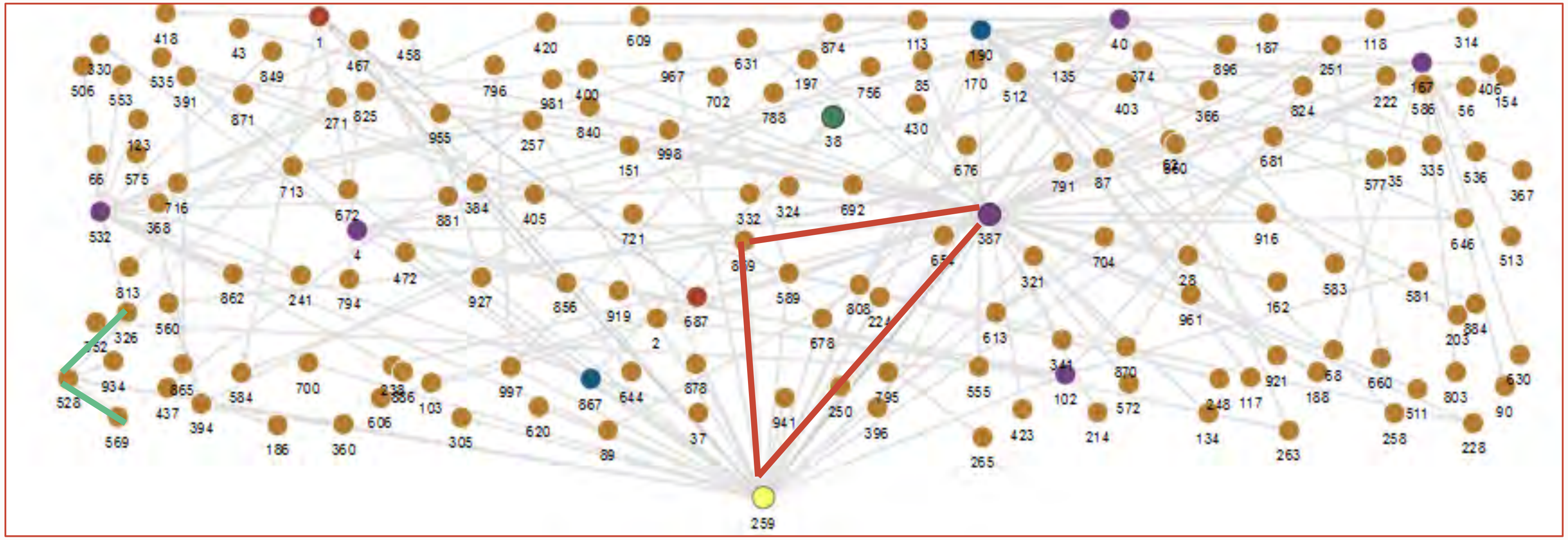


Graph Queries: Finding Patterns in a Graph

Property Graph Query Language (PGQL)

Is there a pattern that connects 528 to 326 and 569?

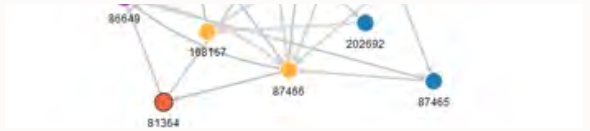
```
SELECT v1, v2, v3, e1,e2
 MATCH (v1)-[e1]->(v2),
 MATCH (v1)-[e2]->(v3)
where v1.id=528 and v2.id=326 and v3.id=569
```



Graph Queries: Finding Patterns in a Graph

Cycles


```
SELECT v1, v2, v3, e1,e2,e3
MATCH (v1)-[e1]->(v2)-[e2]->(v3)-[e3]->(v1)
```

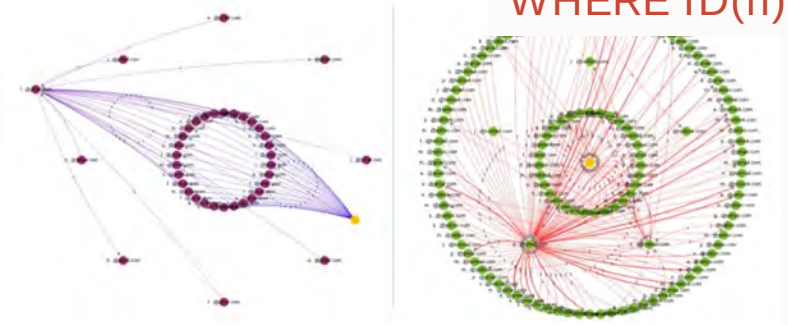


Paths

```
SELECT *
MATCH (n)-/:transfer{1,6}/->(m)
WHERE ID(n) = 1
```

```
SELECT n, ARRAY_AGG(ID(m)), ARRAY_AGG(ID(e))
MATCH TOP 2 SHORTEST ((n) (-[e:transfer]->(m))* (n))
WHERE ID(n) = 1
```

Patterns



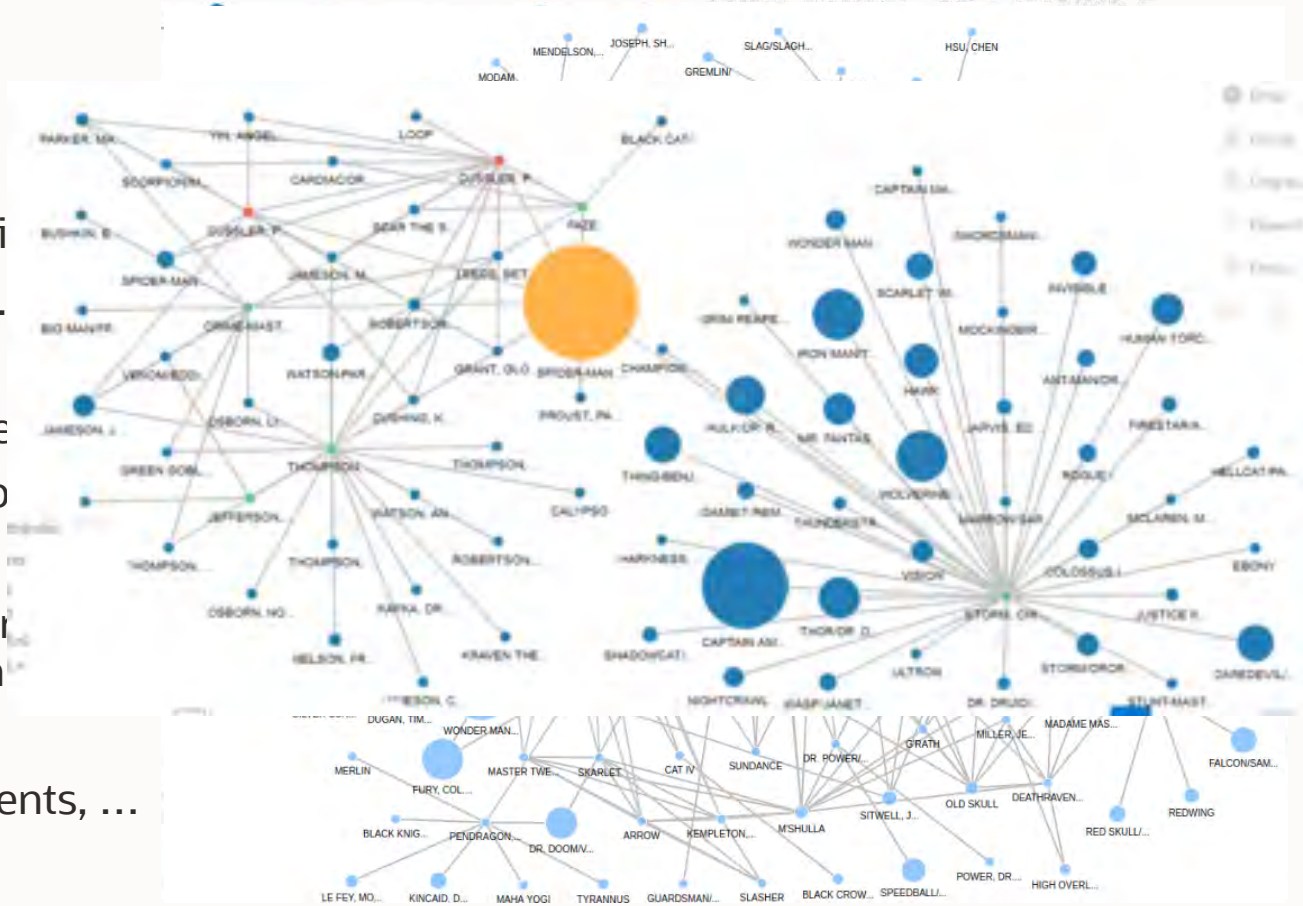
Graph Algorithms

Graph Algorithms

Analyze the full graph

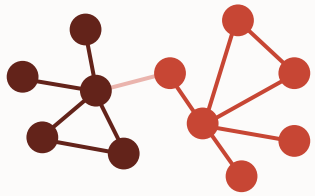
Derive information about:

- What is the value of a vertex in relation to other verti
  - Centrality, PageRank, Betweenness Centrality, …
- In how many ways can you reach vertex B from verte
  - Shortest path, Fattest path, Number of hops in p
- How tightly (or sparsely) is the graph connected? A
  there tightly connected sub-graphs within the graph
  - Are there isolated vertices in the graph?
  - Strongly connected, Weakly connected components, …
- Evaluating structures



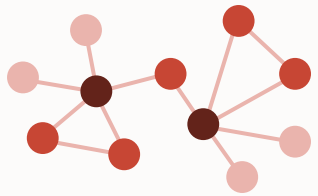
Graph Analytics - 50+ Built-in Algorithms

Detecting Components and Communities



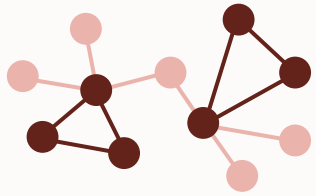
Strongly Connected Components,
Weakly Connected Components,
Label Propagation,
Conductance Minimization,
Infomap

Ranking and Walking



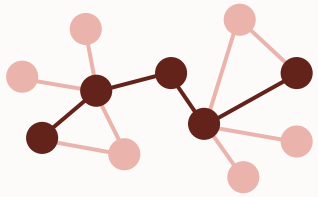
PageRank, Personalized PageRank,
Degree Centrality, Closeness Centrality,
Vertex Betweenness Centrality,
Eigenvector Centrality, HITS, SALSA,
Random Walk with Restart

Evaluating Structures



Adamic-Adar Index, Conductance,
Cycle Detection, Degree Distribution,
Eccentricity, K-Core, LCC, Modularity,
Reachability Topological Ordering,
Triangle Counting

Path-Finding



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

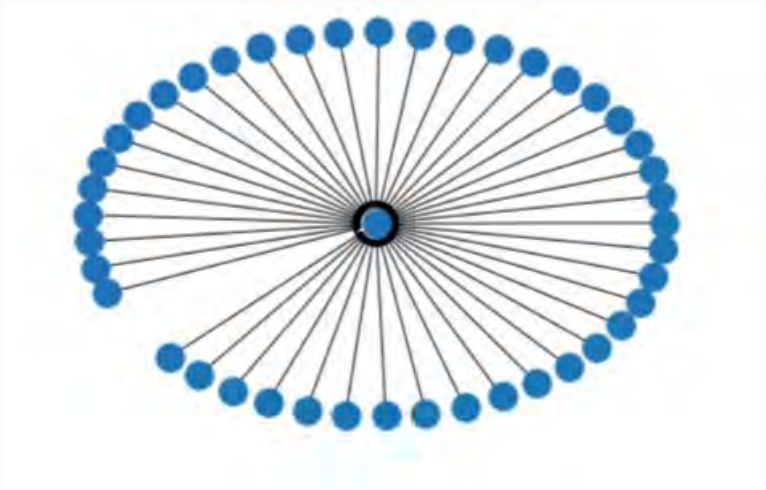
Link Prediction

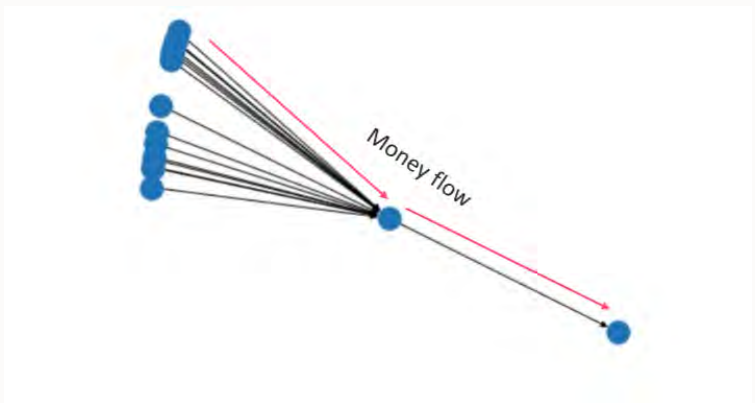
WTF (Who to follow)

Others

Minimum Spanning-Tree,
Matrix Factorization

Ranking: Importance of Vertices

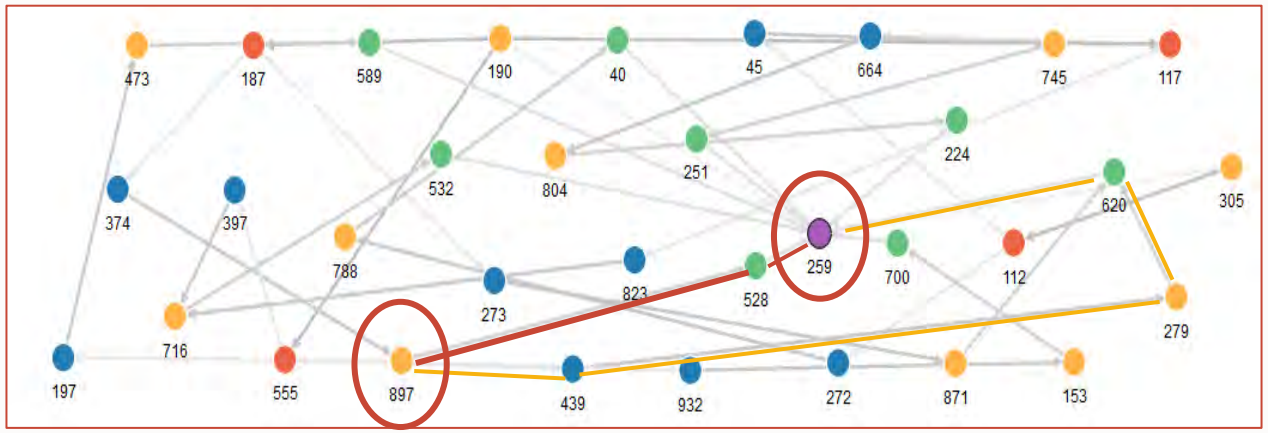


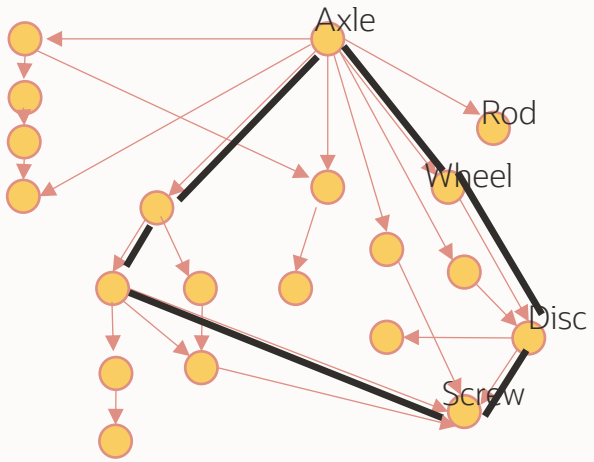


Use cases

- **Financial:** Find accounts through which most of the money flows
- **Retail:** Influencers in a social network, for product recommendation
- **Law enforcement:** Vertices with high betweenness centrality values determine links between groups

Paths between Vertices

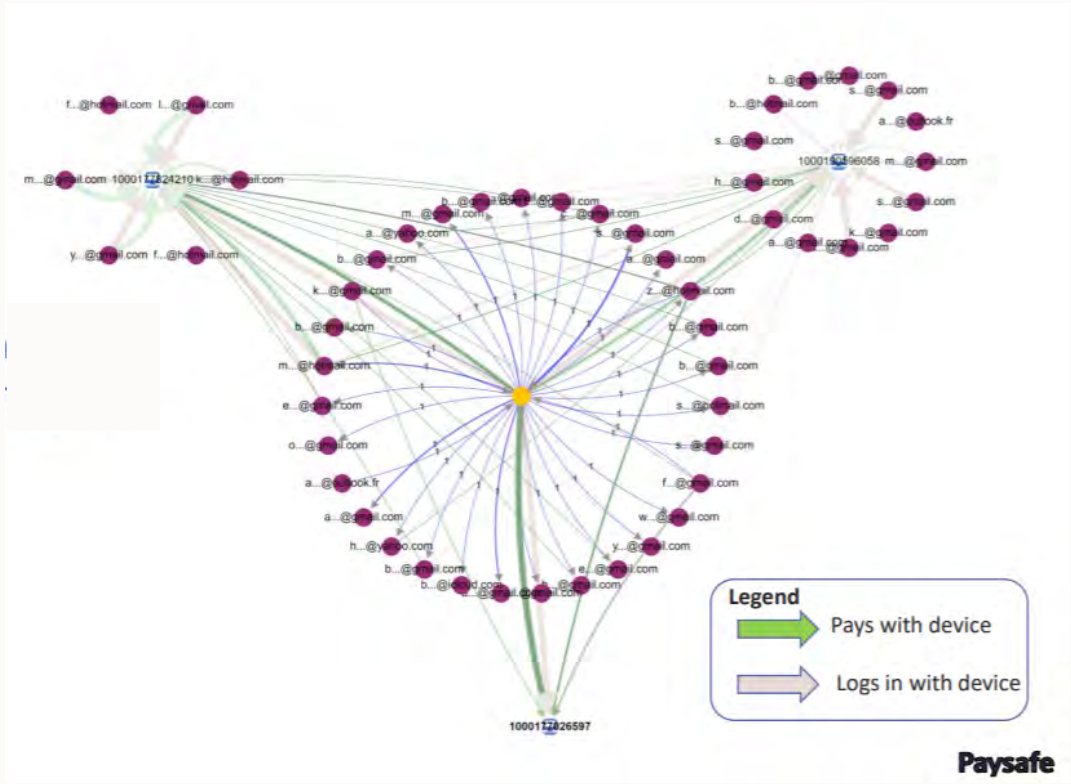




Use cases

- **Telecommunications:** Network management: What-If analysis.
- **Financial:** Was there a cash transfer between these two accounts?
- **Manufacturing:** Dependency analysis in a Bill of Materials graph

Detecting Communities



Use cases

- **Financial:** Does this suspicious account belong to a community of fraudsters?
- **Financial:** Community of users using the same device
- **Retail:** Can behavior of members of the community predict churn?

Running Graph Algorithms

Setup Your Graph Server

Installation: https://github.com/ryotayamanaka/oracle-pg/tree/20.3

Clone repository (Note, the branch is 20.3)

```
$ git clone https://github.com/ryotayamanaka/oracle-pg.git -b 20.3
```

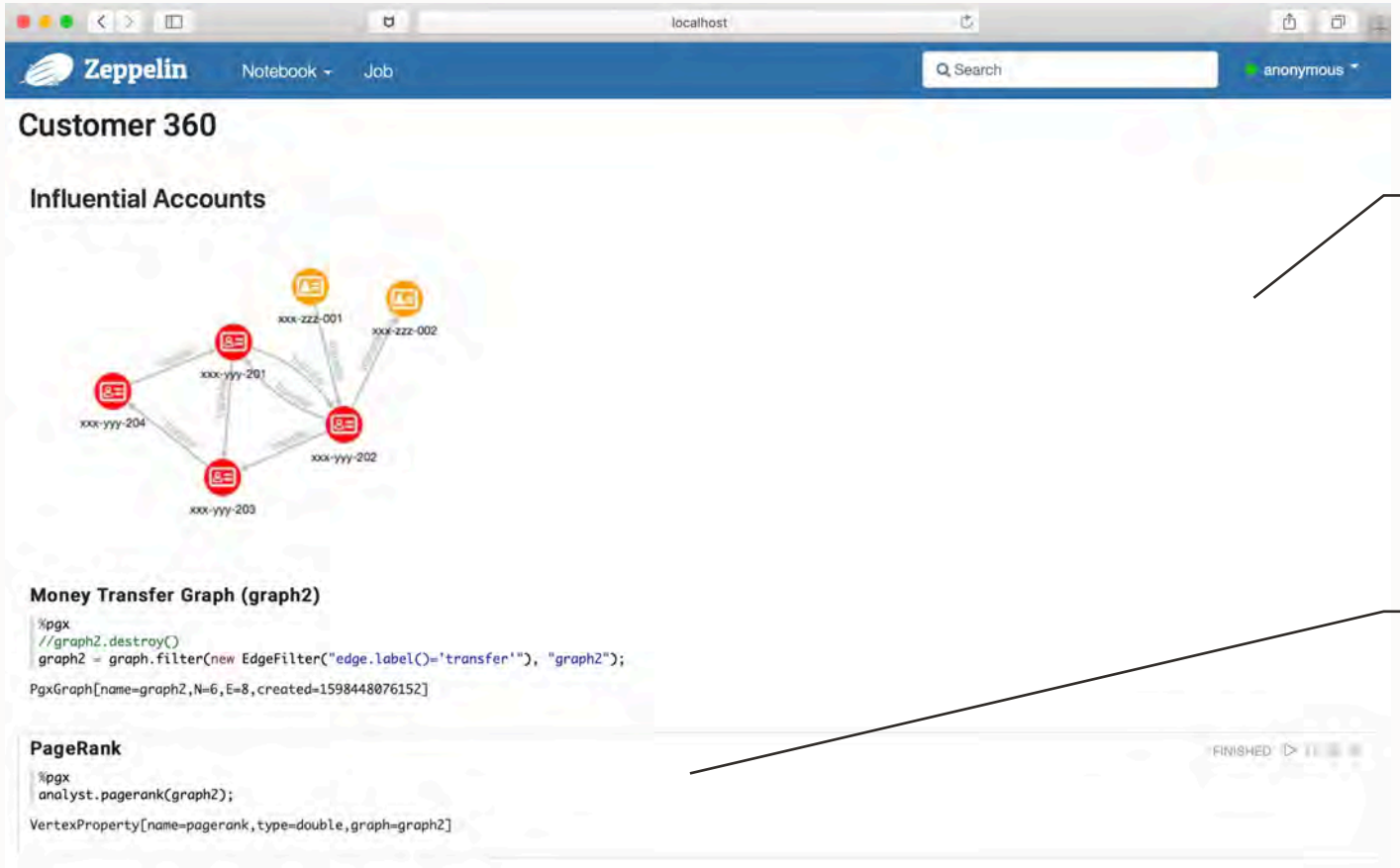
Download and extract packages (Note, the packages are version 20.3)

```
$ sh extract.sh
```

Build and start the docker containers

```
$ docker-compose up -d
```

Run Algorithms from JShell or Zeppelin



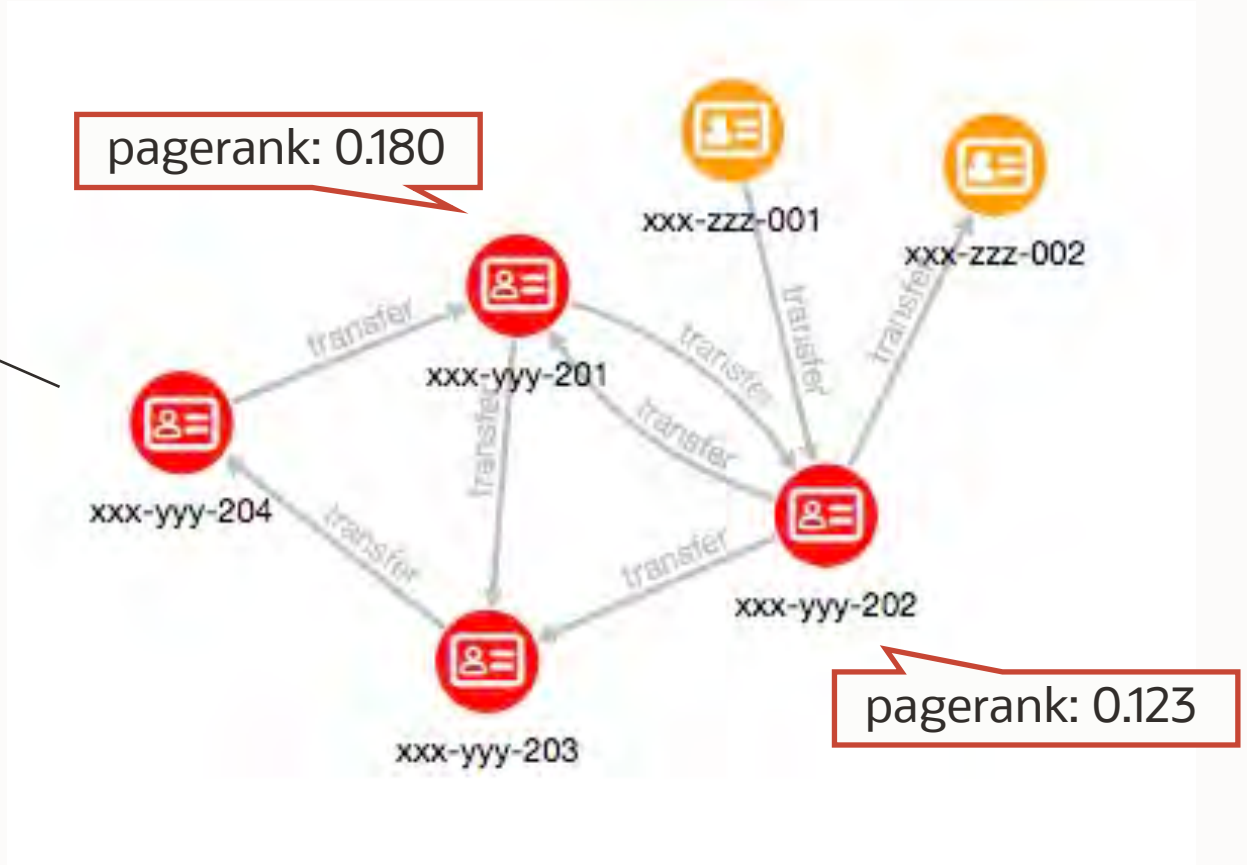
The interpreter for Apache Zeppelin Notebook is provided and Groovy syntax is supported.

(Python API is also planned)

We can run algorithms:
`analyst.pagerank(graph2)`

Write Queries to Get the Results

After running algorithms, the results are stored into the graph, e.g. each node gets a new property "pagerank".



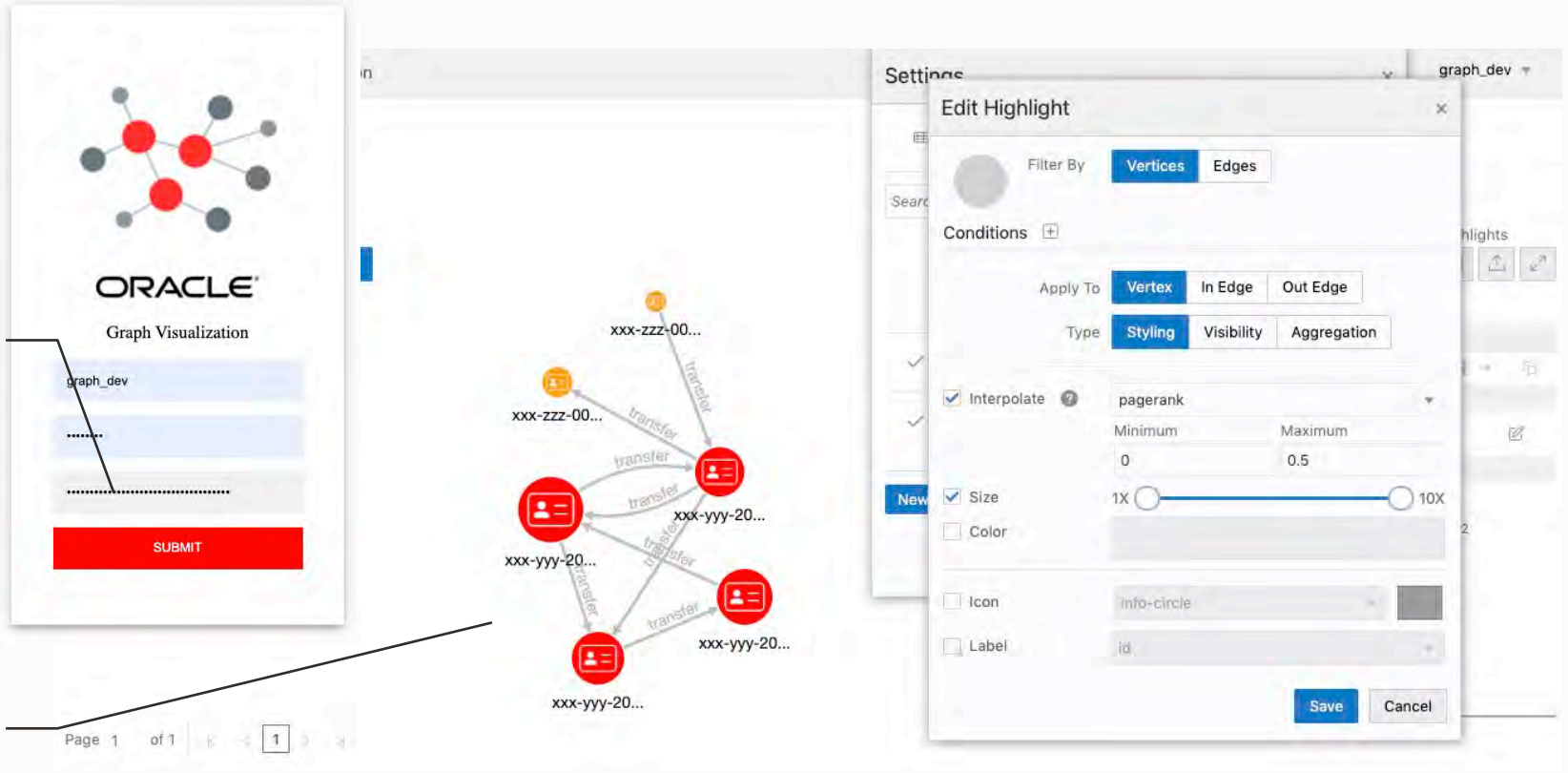
Users can access the results using PGQL queries:

```
SELECT a.account_no, a.pagerank
FROM MATCH (a)
ORDER BY a.pagerank DESC
```

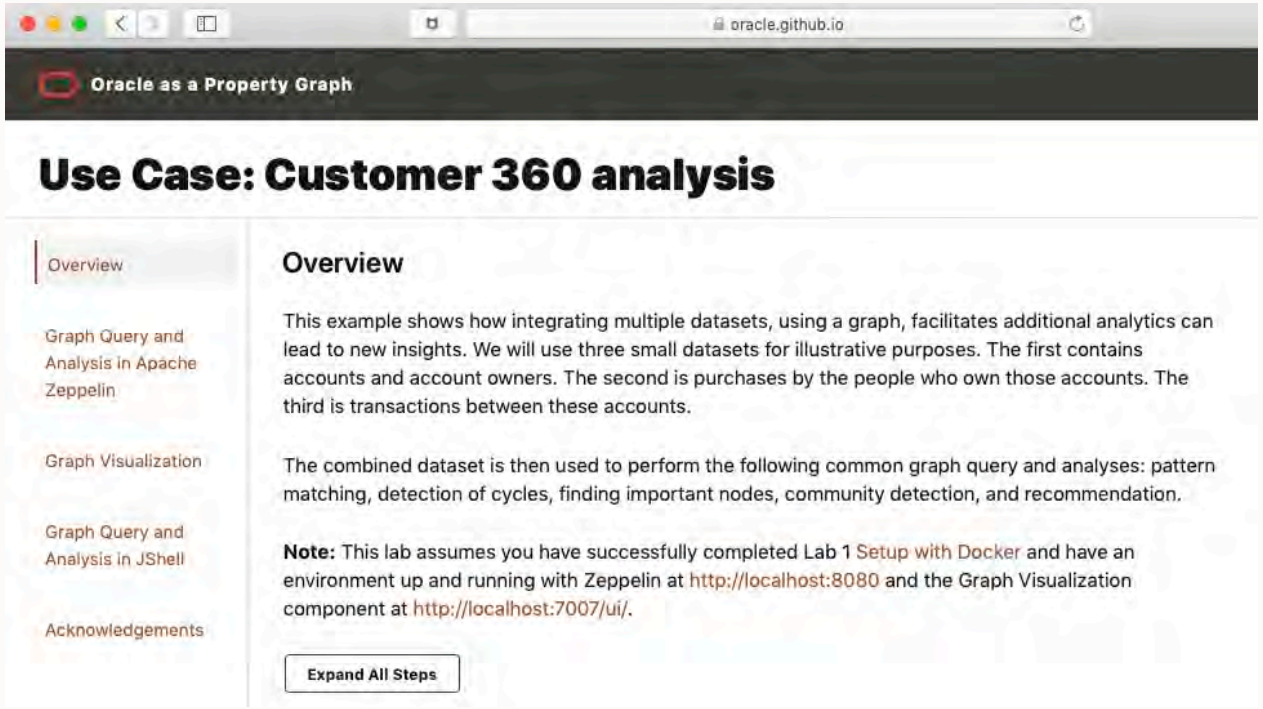
Visualize the Results

Login with the same **session ID** as the one which ran the algorithms.

The size of nodes can be linked to the pagerank scores.



Example - Bank Customer Analysis



https://oracle.github.io/learning-library/data-management-library/database/graph/livelabs/?lab=lab-2-customer-360-analysis

Influential Accounts

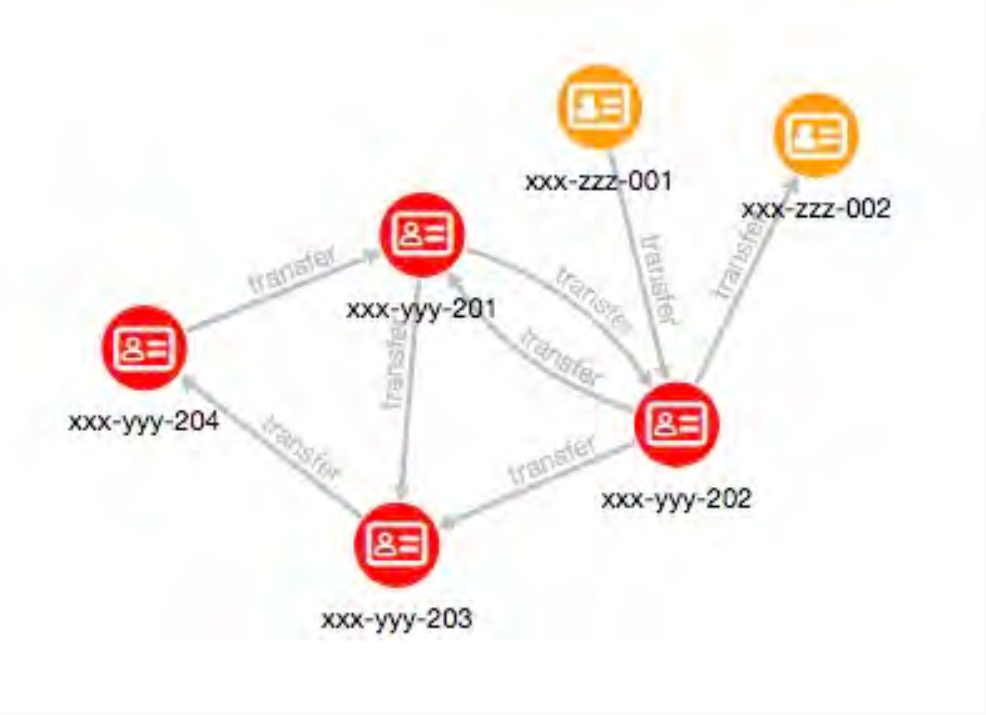
Which is the account with the highest pagerank?

Filter by "transfer" relationship, run **pagerank** algorithm. The result is stored as "pagerank" new node property, and it can be queried.

```
graph2 = graph.filter(new EdgeFilter(
           "edge.label()='transfer'"));
```

```
analyst.pagerank(graph2);
```

```
SELECT a.account_no, a.pagerank
FROM MATCH (a)
ORDER BY a.pagerank DESC
```



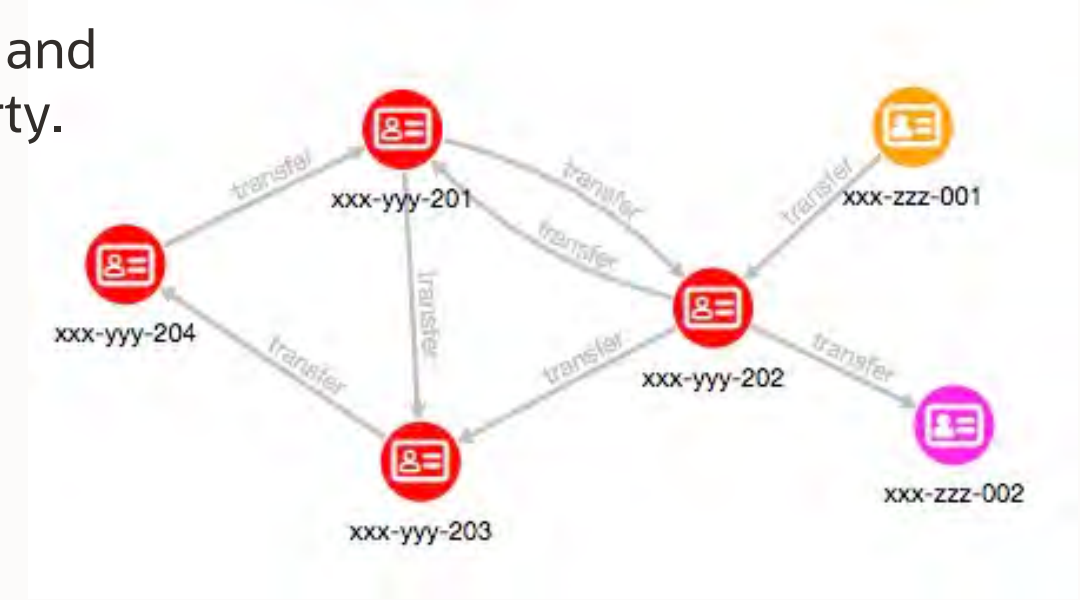
Community Detection

Find the communities where every account is reachable from every other account

Run **strongly connected component** algorithm and reflect the results into "component" node property.

```
result = analyst.sccKosaraju(sg)
```

```
SELECT
  a.scc_kosaraju, COUNT(a.account_no)
FROM MATCH (a)
GROUP BY a.scc_kosaraju
```

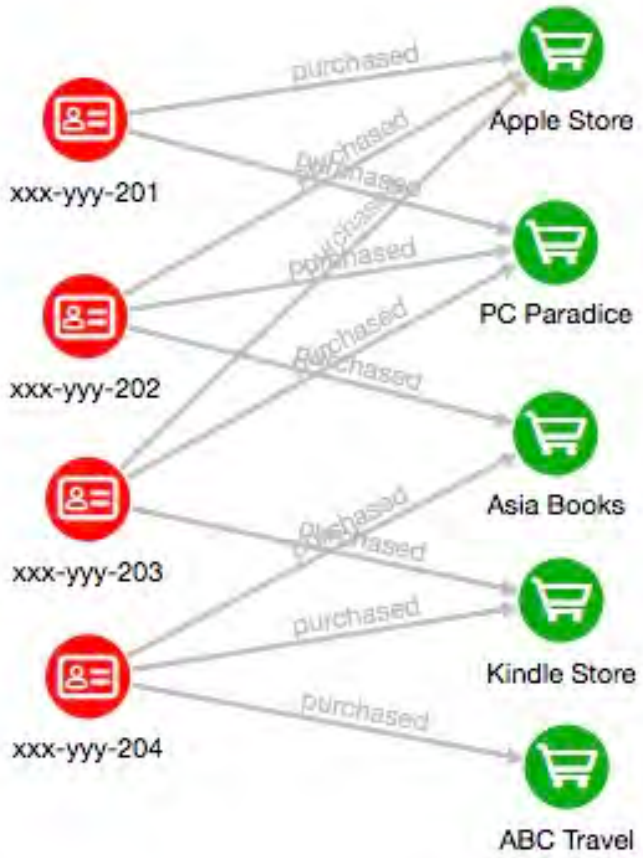


Recommendation

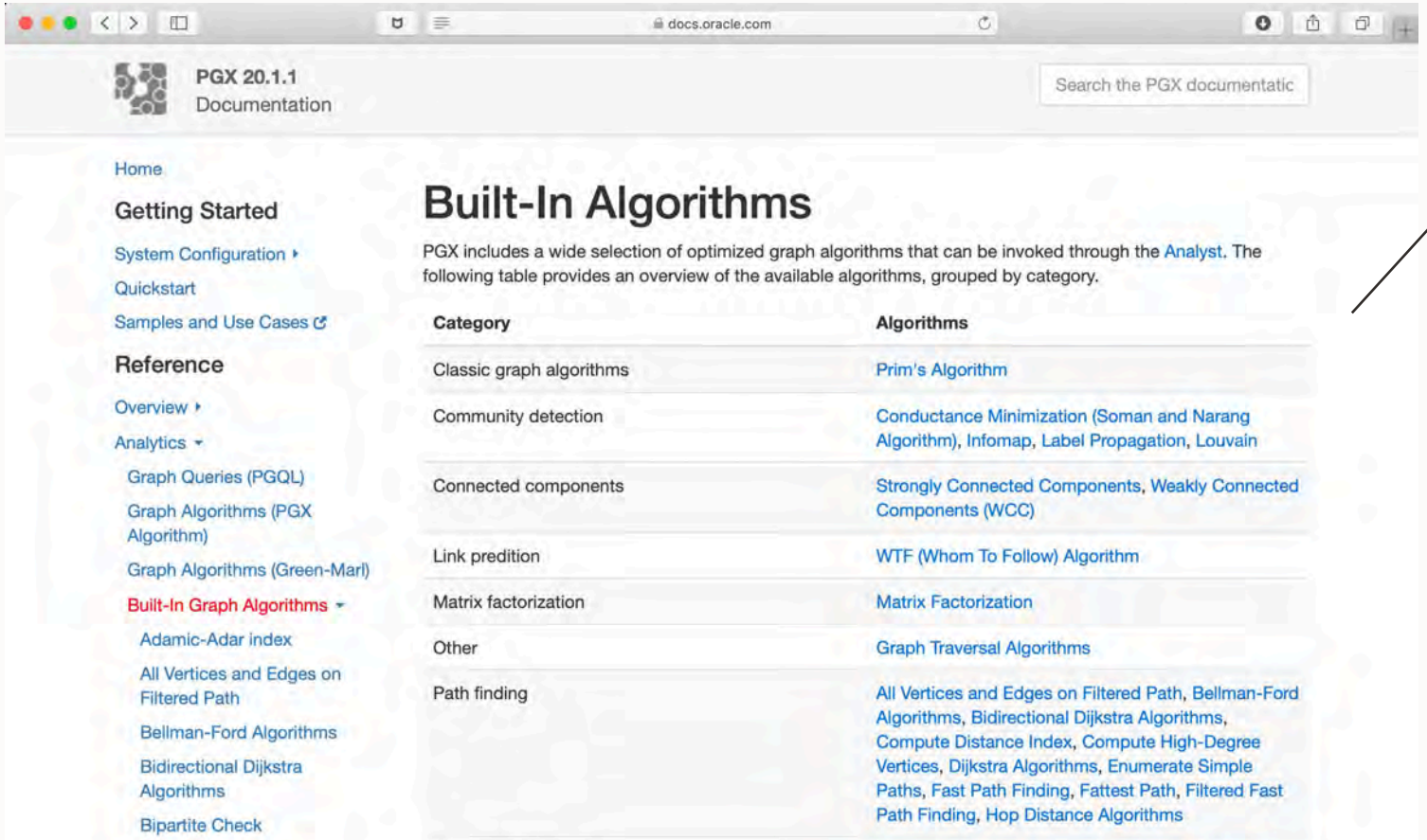
Which merchants should be recommended to the account "-201" based on the purchase history?

Filter by "purchased" relationship, run **personalized pagerank** from the node 201, and then query :

```
SELECT ID(x), x.name, x.pagerank
FROM MATCH (x)
WHERE x.type = 'merchant'
  AND NOT EXISTS (
    SELECT *
    FROM MATCH (x)-[:purchased_by]->(a)
    WHERE ID(a) = 201
  )
ORDER BY x.pagerank DESC
```



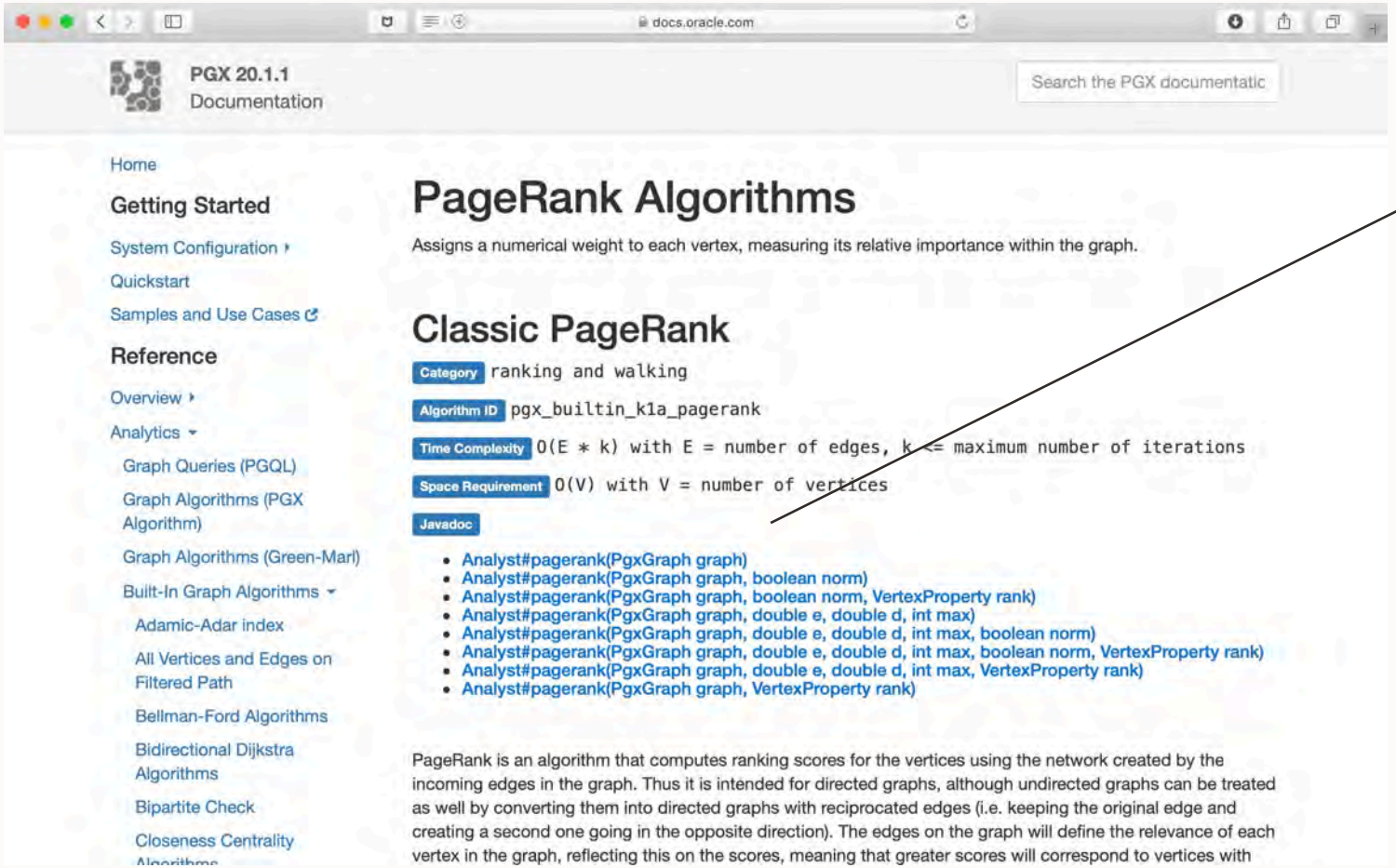
More Algorithms



All built-in algorithms are listed here.

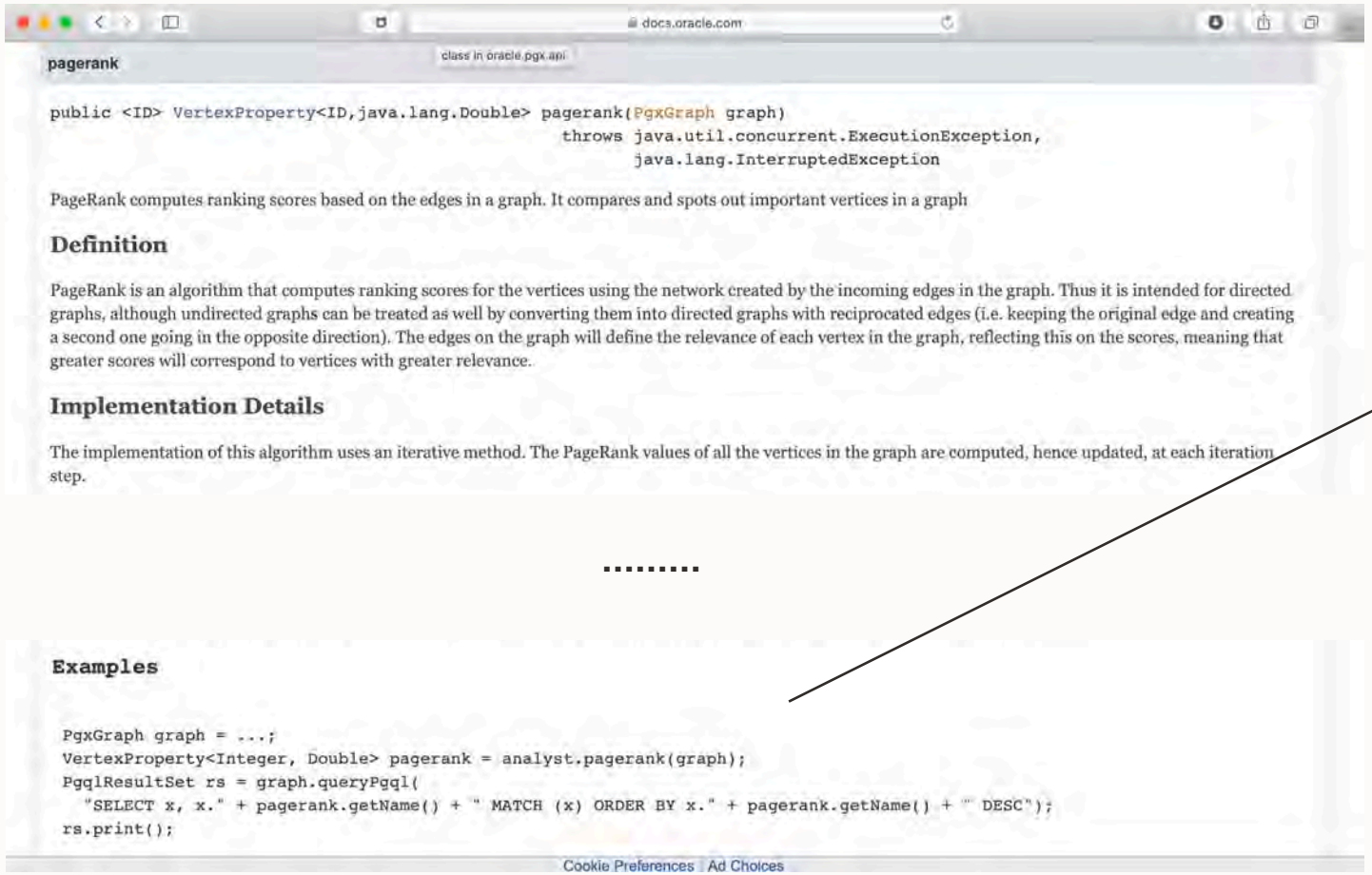
https://docs.oracle.com/cd/E56133_01/latest/reference/analytics/builtins.html

More Algorithms



Each algorithm page provides the description, implementation, and the link to **Javadoc** page.

More Algorithms



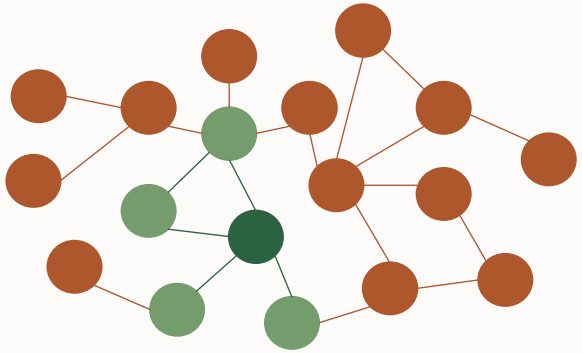
The method section for each algorithm has **examples** to show how it can be used in Java.

Scalability in Graph Analytics

Two Types of Processing in Graph Analytics

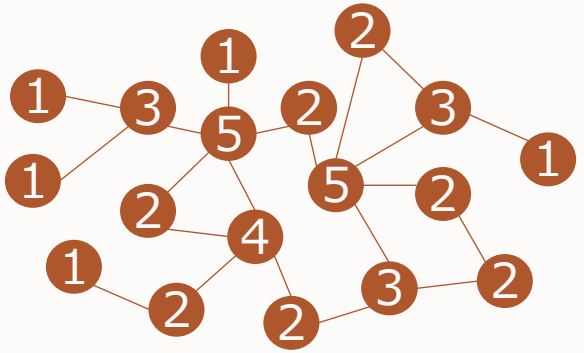
Query

- Search for surrounding nodes
- Traverse property paths
- Pattern matching
- Extract sub-graphs



Algorithm

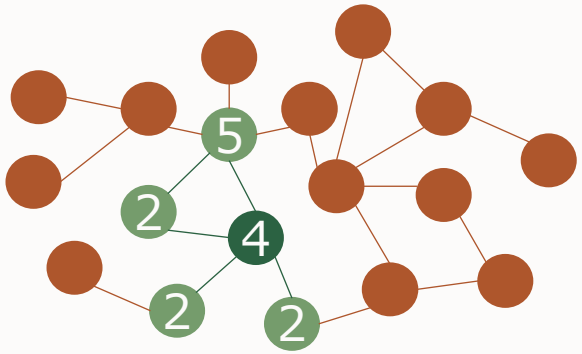
- Rank importance of nodes
- Detect components and clusters
- Evaluate structure of communities
- Shortest paths

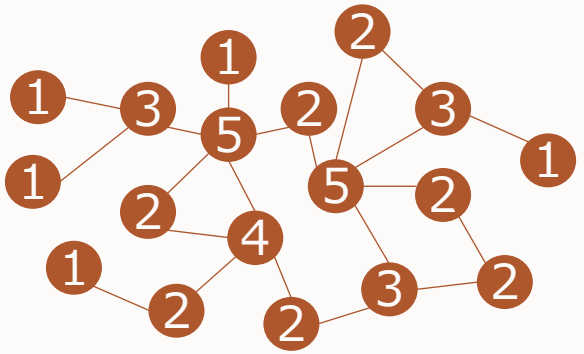


Two Types of Processing in Graph Analytics

Oracle Graph Server can execute both queries, algorithms, mutation (simplify, filter, …) and their combination.

Which is the node in 3 steps from my node, and has the highest pagerank among them?



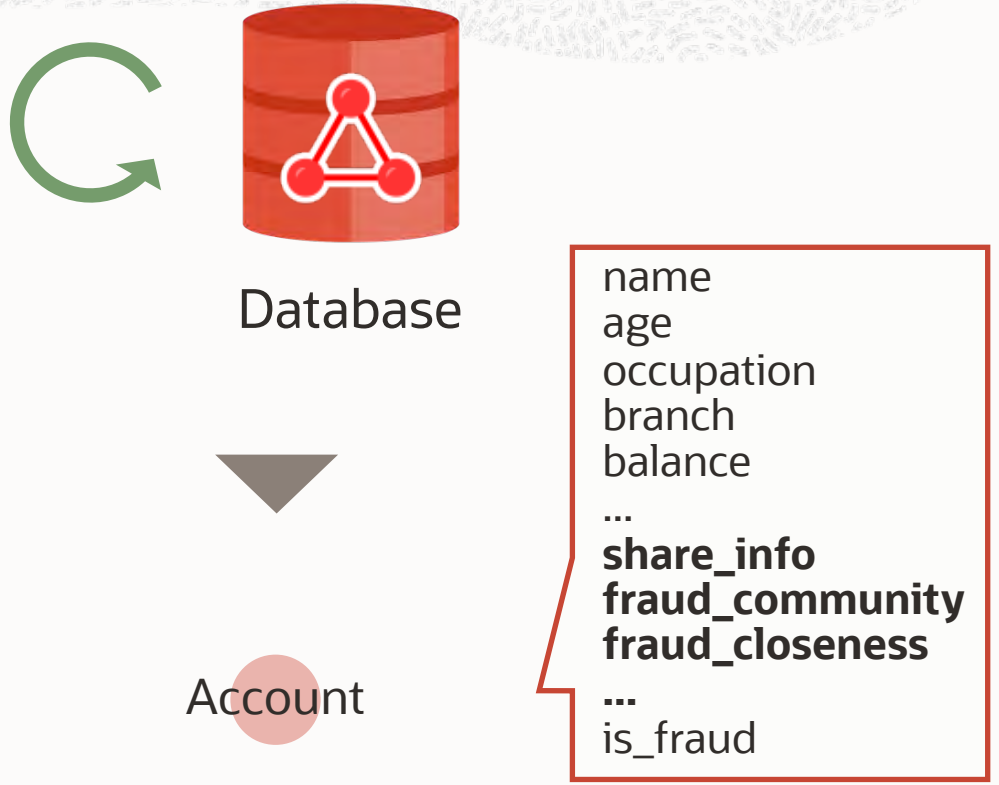


Graph Algorithms and Analysis Flows

Pattern 1 - Finding significant nodes

1. Run graph algorithms for scoring all nodes
   - ranking (centrality, pagerank, ...)
   - community detection
2. The scores (=new features) are used for:
   - finding high score nodes
   - as conditions in graph query
   - as machine learning input

- Use Cases
  - Financial fraud detection, Tax fraud detection, Influencer detection, Anormal behavior detection in cyber security, Scoring importance of devices in networks (utility and communication)



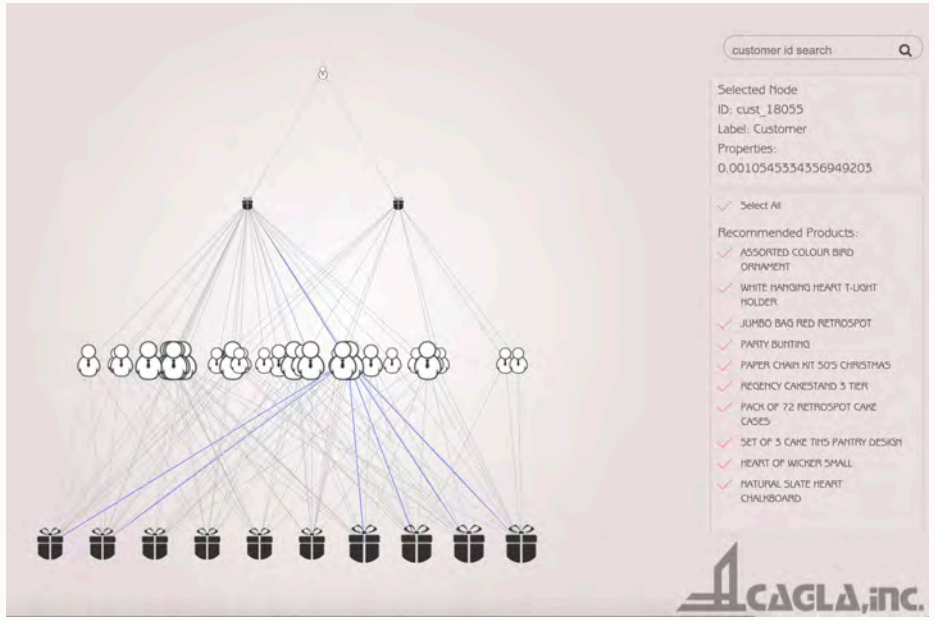
Mule account detection
(AskTOM - May 28, 2020)

Graph Algorithms and Analysis Flows

Pattern 2 - Enabling advanced queries

1. Select specific node(s)
2. Run graph algorithms against the node(s)
   - personalized ranking (PPR, ...)
   - community detection
   - reachability
3. Query to return the results to applications:
   - often real-time

- Use Cases
  - Reachability between devices (utility and communication), Recommendation for a customer (retail), Find other members in the same community (fraud and crime analysis)

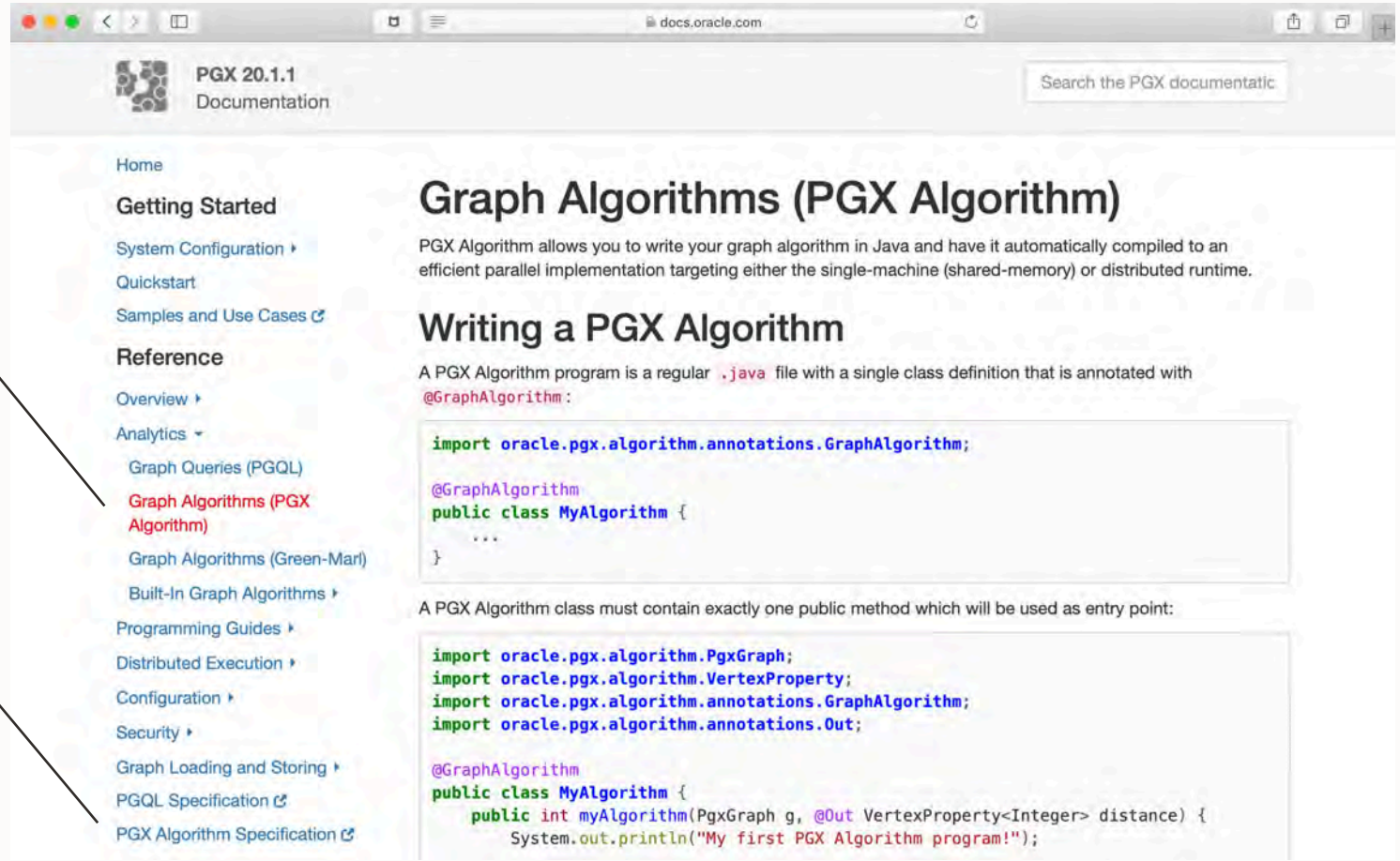


Real-time recommendation app (AskTOM - July 2, 2020)

Custom Algorithms

PGX Algorithm is a Java-syntax language to write custom graph algorithms (Using Green-Marl is not supported)

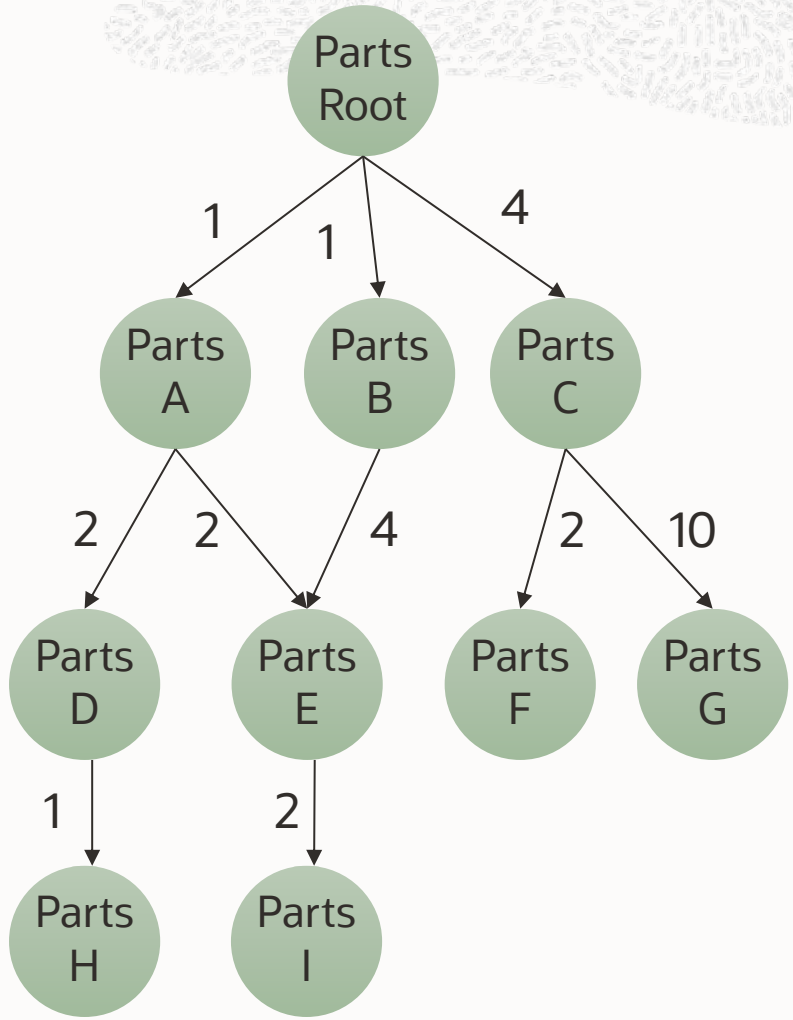
PGX Algorithm **specification** is here. Also, each built-in algorithm page shows their implementations in PGX Algorithm.



Custom Algorithms

Use case of custom algorithm in **Manufacturing BoM** (bill of materials):

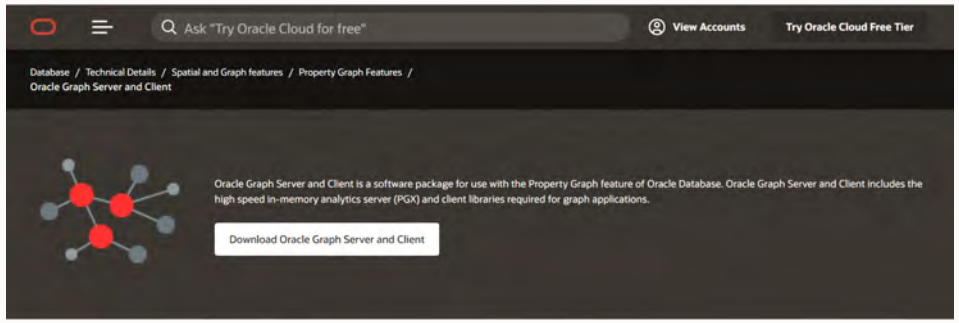
- Some of the calculation processes can be optimized, implementing them as **stored programs** on Graph Server.
- E.g. sum up the numbers of parts in a BoM tree.
  - One-time traversal from the root node (BFS: breath first search) calculates the numbers of all parts and the graph can keep the results as node properties.



ID	num
A	1
B	1
C	4
D	2
E	6
F	8
G	40
H	2
I	12

Helpful Links

Search for "Oracle Graph Server and Client" to download from oracle.com



- Graphs at Oracle
  https://www.oracle.com/goto/graph
- Oracle Property Graph
  http://www.oracle.com/goto/propertygraph
- Blog: Examples, Tips and Tricks
  http://bit.ly/OracleGraphBlog
- AskTOM Series: https://asktom.oracle.com/pls/apex/asktom.search?office=3084
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  - LinkedIn: Oracle Spatial and Graph Group
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AskTOM Office Hours: Graph Database and Analytics

- Welcome to our AskTOM Graph Office Hours series!
  We're back with new product updates, use cases, demos and technical tips
  https://asktom.oracle.com/pls/apex/asktom.search?oh=3084
- Sessions will be held about once a month
- **Subscribe** at the page above for updates on upcoming session topics & dates
  And submit feedback, questions, topic requests, and view past session recordings
- Note: **Spatial** now has a new Office Hours series for location analysis & mapping features in Oracle Database:
  https://asktom.oracle.com/pls/apex/asktom.search?oh=7761

Our mission is to help people
see data in new ways, discover insights,
unlock endless possibilities.

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