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Graph Database

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GRAPH DATABASE

By

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B.S., Southern Illinois University, Edwardsville, 1992

GRADUATE PROJECT

Submitted in partial fulfillment of the requirements
For the Degree of Master of Science,
With a Major in Computer Science

Governors State University
University Park, IL 60484

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Abstract

This project will review the new technology of graph databases. Graph databases, which model data using nodes and relationships, utilize a different paradigm than the rows and columns of relational databases.

The main goals of this project are to provide the basic background information on graph database technology and then use this knowledge to convert an RDBMS into a GDBMS. The RDBMS used will be the sample Accounts Payable (AP) relational database used in the Murach SQL 2012 book. The following will be accomplished:

- Explore graph database versus relational for querying and updating the Accounts Payable database. Review Cypher (Neo4j graph query language) and run CRUD queries against the AP graph database.
- Show step by step instructions to convert the Murach SQL 2012 Accounts Payable database into the graph database.
Getting Started

Setup a graph database
The graphs database used for this project is called Neo4j. It’s java based so be sure to download the Java Development Kit (JDK). The community edition is open sourced and can be downloaded for free. There is also an advanced server edition too for commercial purposes. Just visit the website called http://www.neo4j.com and select download. After installing, run the startup application program. Note: The real application program is a browser-based application.

![Neo4j Community](image)

Figure 1 Main Window for Neo4j

The database server will be in a stopped stated because the default database has not been created. Press start and the database will be created for you in the database location. The database status will then provide a hyperlink to browser-based application. Press the hyperlink and it will launch the browser application.

Running Neo4j in the Browser
Most work will be accomplished in the extremely functional browser application. Here is where queries are run, files are imported and most importantly the graph database nodes and relationships are displayed.
Running Neo4j at the Console
For some, the console is preferred. To launch the console, go to the Main Window for Neo4j and press the Options button. Then press the Command Prompt button.

Graph Database Background

Graph nodes and relationships
Data structured in graphs rather than in tables represent a paradigm shift for connection data. Graphs use node and relationships, not rows and columns.
Nodes are like rows in a table. A node has a type (like a table name in relational) and some properties (key/value pairs), like name, id, and state. See the figure below for a graphical representation of nodes.

Relationships are used to connect nodes together. Just like nodes, relationships can have properties (key/value pairs) too. This is in contrast to RDBMS that use foreign keys and join table to connect data. In the figure below, this relationship has one property called Joined with a value of 1/1/15.

Putting the two key components together, we can say that node (a) Vendor “belongs to” node (b) Industries. See figure below.

One advantage when drawing nodes and relationships into more complex data models is that the actual graph database almost exactly follows the whiteboard model. In the example below for the AP database, the left side is a drawing done in Microsoft Visio whereas the right side is an actual graph database in Neo4j. See figure below.
As you can see the white board drawing is almost identical to the actual working graph database!

Lastly to provide insights into the powerful expressiveness of graph databases, the figure below is graph of a graph database structure. A graph records nodes and relationships. Nodes and relationships have properties and relationships organize nodes.
To wrap up the rules for nodes and relationships, Ian Robinson and James Webber in Graph Databases, 2nd Ed summarize a graph database succinctly:

- It contains nodes and relationships.
- Nodes contain properties (key-value pairs).
- Nodes can be labeled with one or more labels.
- Relationships are named and directed, and always have a start and end node.
- Relationships can also contain properties.

**CRUD – Create, Retrieve, Update, Delete**

**Create**
Since we now know how graphs are structured, let’s use Cypher (the DML SQL equivalent language) for creating a node, in this case Vendor. Use the keyword “create” followed by an open parenthesis, then the properties (key/value pairs) surround by curly braces, then a close parenthesis. The open/close parenthesis encapsulate a node.

```cypher
CREATE (v:Vendor { id:3, name: 'Register of Copyrights', city:'Washington DC', state:'53',defaultTerm:3, defaultAccount:403})
```

There is another way to create a node by use of “merge” which combines a match and create, i.e., don’t create if a match is found.

The neo4j console provides a template to help you create nodes and relationships. An example below is provided that will create two nodes, a Vendor called Packt and an Industry of Publishing and then create a relationship of Belongs_To between these nodes. See figure below.
### Using Data

<table>
<thead>
<tr>
<th>Create</th>
<th>Create a &quot;Vendor&quot; node with a property called &quot;name&quot; that has value &quot;Packt&quot;. (Or create Node B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><code>CREATE (:Vendor { name: 'Packt' }) RETURN n</code></td>
</tr>
<tr>
<td></td>
<td><code>CREATE (:Industry { name: 'Publishing' }) RETURN n</code></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relate</th>
<th>From a &quot;Vendor&quot; node with a &quot;name&quot; property of &quot;Packt&quot; create a &quot;BELONGS_TO&quot; relationship to a &quot;Industry&quot; with &quot;name&quot; value &quot;Publishing&quot;.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><code>MATCH (:Vendor { name: 'Packt' }), (:Industry { name: 'Publishing' }) CREATE (:Vendor)-[:BELONGS_TO]-&gt;(:Industry)</code></td>
</tr>
</tbody>
</table>

### Merge node

<table>
<thead>
<tr>
<th>Merge node</th>
<th>Find or create a &quot;Vendor&quot; node with &quot;name&quot; of &quot;Packt&quot;.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><code>MERGE (:Vendor { name: 'Packt' }) RETURN n</code></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Merge relationship</th>
<th>Find or create a relationship from a &quot;Vendor&quot; with &quot;name&quot; of &quot;Packt&quot; through a &quot;BELONGS_TO&quot; relationship to a &quot;Industry&quot; node with &quot;name&quot; of &quot;Publishing&quot;.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><code>MATCH (:Vendor { name: 'Packt' }), (:Industry { name: 'Publishing' }) CREATE (:Vendor)-[:BELONGS_TO]-&gt;(:Industry)</code></td>
</tr>
</tbody>
</table>

### Retrieve

Retrieval as mentioned above use the match keyword, match needs a label (which is like a table name in SQL) and specific properties to search on. The identifier used with the label is then used to store the return value.

```cypher
$ match (i:Industry {IndustryID:'7'}) return i;
```

A powerful feature of Cypher is an easy way to retrieve all the relationships between all the nodes. The way to specify a match on (a)-[r]->(b) where any node is related to any other node. See figure below.

1. `MATCH (a)-[r]->(b)`
2. `RETURN DISTINCT head(labels(a)) AS This, type(r) as To, head(labels(b)) AS That`
You can also retrieve a graph structure by using similar syntax above but in this case return the identifiers used to store the labels of connecting nodes:

\[
\text{MATCH (i:Invoice (InvoiceID: "12")[:CONTAINS]->(l:InvoiceItems) return i,l:}
\]

One final example of retrieval is a multi-join that can return all line items for a vendor. It will match on “vendor->Invoice->InvoiceLineItems”

```
match (v:Vendor)-->(:Invoice)-->(:InvoiceLineItems)
return v.VendorName as Company, collect(distinct l.InvoiceLineItemDescription) as LineItems
```

### Update

Updates in Cypher follow the same pattern as create and retrieve, namely find a match first. In the update, simply set the property associated with the identify used for a particular label.

\[
\text{MATCH (n:Industry (Name: 'Health Care')) set n.Name='Telecommunications' RETURN n}
\]

### Delete

When deleting a node, make sure you also remove the connecting relationships, otherwise the remove will fail. In the case below, LineItem with InvoiceID 33, Sequence 1 should be deleted. However, since the InvoiceLineItem is connected via a relationship to an Invoice, that relationship must be deleted too. So in the Cypher statement below, both the node and relationship are deleted.
Relational Database
In contrast to an Entity Relationship Diagram (ERD) for a database, there is no schema for a graph database. A graph database is “schema-less” but it is still possible to abstract the node and relationship details into a diagram. Also, when exporting data from Relational it is not necessary to export the database schema.

Creating a Graph Database
Constructing the Graph Database
From SQL Server, export each database table (with Headers included) as a CSV file. Then execute the LOAD statement in Neo4j. For this project there are four tables thus there are four CSV files. Each CSV file will be loaded into Neo4j. Note: Neo4j provides an example of importing the NorthWind database. This helpful step-by-step example can be found in the information page of the browser application.

Creating Nodes
Color Code

Manual way to create a node:

Command: CREATE (vendor3:Vendor { id:3, name: 'Register of Copyrights', city:'Washington DC', state:'', defaultTerm:3, defaultAccount:403})

Response: Added 1 label, created 1 node, set 6 properties

Query: match (v:Vendor { id : 1 }) return v

Response:

Set Query: match (v:Vendor { id : 2 }) set v.state='DC' return v
Response: . When clicking on node, Vendor information confirms state change:

CSV alternative:

load csv with headers from "file:///C:/AP/Vendors.CSV" as row create (n:Vendor) set n = row

Added 122 labels, created 122 nodes, set 1464 properties,

Note that vendors have no relationships yet.

$load csv with headers from "file:///C:/AP/Invoices.CSV" as row create (n:Invoice) set n = row

Note that Invoices display InvoiceID, similar to Vendors displaying VendorID. We’ll see later on the node’s display is configurable and in fact with graph style sheets can have multiple properties displayed for a single node.

Create Indexes

Now we will create indexes on the node Labels. This will allow faster retrieval when filtering by Labels.

create index on :Invoice(InvoiceID)

Added 1 index, statement executed in 67 ms.
Creating Relationships
The next step will create a relationship between Invoice and Vendor. It will do so without the usage of foreign keys, but instead with a create relationship statement, that is invoked after the same IDs from Invoices and Vendors are matched together.

```
match (i:Invoice),(v:Vendor) where i.VendorID = v.VendorID create (v)-[:FULFILLS]->(i)
```

Response: Created 114 relationships, statement executed in 136 ms.

Next the Invoice Line Items will be added.

```
$ load csv with headers from "file:///C:/AP/InvoiceLineItems.CSV" as row create (n:InvoiceLineItems) set n = row
```

Response: Added 118 labels, created 118 nodes, set 590 properties

Again the relationships will be created to “join” each Invoice with its associated Line Items.

```
match (i:Invoice),(l:InvoiceLineItems) where i.InvoiceID = l.InvoiceID create (i)-[:CONTAINS]->(l)
```

Response: Created 118 relationships.

Now to add complexity to the graph database, I created an Industry table that stored 10 unique industries. To tie a Vendor to an Industry this requires a many-to-many relationship from Vendors to Industries. To model this in SQL, a juncture table for VendorIndustry would need to be created expressly to store the foreign keys of Vendors and Industries. However in Neo4j, fortunately direct relationships are created between Vendors and Industries.

```
load csv with headers from "file:///C:/AP/Industry.CSV" as row create (n:Industry) set n = row
```

Response: Added 10 labels, created 10 nodes, set 20 properties.

Check an example industry: match (i:Industry {Name: "Technology"}) return i

Response:

Now to link Vendors to Industries, a match of both types is followed by equivalence checks on respective ID values, then followed by a create relationship command of Vendors belong to Industries.

```
load csv with headers from "file:///C:/AP/VendorIndustry.CSV" as row
match (v:Vendor), (i:Industry)
```

Response:
where v.VendorID = row.VendorID AND i.IndustryID = row.IndustryID

create (v)-[:BELONG_TO]->(i)

set vendors = row

Response: Set 244 properties, created 122 relationships.

**Final Result**
When all nodes and relationships are imported, the result is

```
$ match (n) return n;
```

![](image)

**Figure 2 Actual Graph Database of Accounts Payable**

**Reference Table – Industry**

<table>
<thead>
<tr>
<th>IndustryID</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Oil and Gas</td>
</tr>
<tr>
<td>1</td>
<td>Basic Materials</td>
</tr>
<tr>
<td>2</td>
<td>Industrials</td>
</tr>
<tr>
<td>3</td>
<td>Consumer Goods</td>
</tr>
<tr>
<td>4</td>
<td>Health Care</td>
</tr>
<tr>
<td>5</td>
<td>Consumer Services</td>
</tr>
<tr>
<td>6</td>
<td>Telecommunications</td>
</tr>
<tr>
<td>7</td>
<td>Utilities</td>
</tr>
<tr>
<td>8</td>
<td>Financials</td>
</tr>
<tr>
<td>9</td>
<td>Technology</td>
</tr>
</tbody>
</table>

**Reference Table – VendorIndustry**

<table>
<thead>
<tr>
<th>VendorID</th>
<th>IndustryID</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>US Postal Service</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>National Information Data Ctr</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Register of Copyrights</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>Jobtrak</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>Newbrige Book Clubs</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>California Chamber Of Commerce</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>Towne Advertiser's Mailing Svcs</td>
</tr>
<tr>
<td>Page numbers</td>
<td>Vendors</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>US Postal Service Madison WI 53707</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>National Information Data Ctr Washington DC 20090</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Register of Copyrights Washington DC 20559</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Jobtrak Los Angeles CA 90025</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Newbrige Book Clubs Washington NJ 7882</td>
<td></td>
</tr>
</tbody>
</table>

This table is only needed for the Import and is not modeled as a separate join table (as it is in relational).

**Data Table – Vendors**

<table>
<thead>
<tr>
<th>vendorid</th>
<th>vendorname</th>
<th>city</th>
<th>state</th>
<th>zip</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>US Postal Service</td>
<td>Madison</td>
<td>WI</td>
<td>53707</td>
</tr>
<tr>
<td>2</td>
<td>National Information Data Ctr</td>
<td>Washington</td>
<td>DC</td>
<td>20090</td>
</tr>
<tr>
<td>3</td>
<td>Register of Copyrights</td>
<td>Washington</td>
<td>DC</td>
<td>20559</td>
</tr>
<tr>
<td>4</td>
<td>Jobtrak</td>
<td>Los Angeles</td>
<td>CA</td>
<td>90025</td>
</tr>
<tr>
<td>5</td>
<td>Newbrige Book Clubs</td>
<td>Washington</td>
<td>NJ</td>
<td>7882</td>
</tr>
</tbody>
</table>

**Parent Data Table – Invoices**

<table>
<thead>
<tr>
<th>Invoi ceID</th>
<th>Vendo rID</th>
<th>InvoiceNumbe r</th>
<th>InvoiceDate</th>
<th>InvoiceT otal</th>
<th>PaymentT otal</th>
<th>CreditT otal</th>
<th>Terms ID</th>
<th>InvoiceDueDate</th>
<th>PaymentD ate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>122</td>
<td>989319-457</td>
<td>12/8/2011 00:00</td>
<td>3813.33</td>
<td>3813.33</td>
<td>0</td>
<td>3</td>
<td>1/8/2012 00:00</td>
<td>1/7/2012 00:00</td>
</tr>
<tr>
<td>2</td>
<td>123</td>
<td>263253241</td>
<td>12/10/2011 00:00</td>
<td>40.2</td>
<td>40.2</td>
<td>0</td>
<td>3</td>
<td>1/10/2012 00:00</td>
<td>1/14/2012 00:00</td>
</tr>
<tr>
<td>3</td>
<td>123</td>
<td>963253234</td>
<td>12/13/2011 00:00</td>
<td>138.75</td>
<td>138.75</td>
<td>0</td>
<td>3</td>
<td>1/13/2012 00:00</td>
<td>1/9/2012 00:00</td>
</tr>
<tr>
<td>4</td>
<td>123</td>
<td>2-000-2993</td>
<td>12/16/2011 00:00</td>
<td>144.7</td>
<td>144.7</td>
<td>0</td>
<td>3</td>
<td>1/16/2012 00:00</td>
<td>1/12/2012 00:00</td>
</tr>
<tr>
<td>5</td>
<td>123</td>
<td>963253251</td>
<td>12/16/2011 00:00</td>
<td>15.5</td>
<td>15.5</td>
<td>0</td>
<td>3</td>
<td>1/16/2012 00:00</td>
<td>1/11/2012 00:00</td>
</tr>
<tr>
<td>6</td>
<td>123</td>
<td>963253261</td>
<td>12/16/2011 00:00</td>
<td>42.75</td>
<td>42.75</td>
<td>0</td>
<td>3</td>
<td>1/16/2012 00:00</td>
<td>1/21/2012 00:00</td>
</tr>
<tr>
<td>7</td>
<td>123</td>
<td>963253237</td>
<td>12/21/2011 00:00</td>
<td>172.5</td>
<td>172.5</td>
<td>0</td>
<td>3</td>
<td>1/21/2012 00:00</td>
<td>1/22/2012 00:00</td>
</tr>
<tr>
<td>8</td>
<td>89</td>
<td>125520-1</td>
<td>12/24/2011 00:00</td>
<td>95</td>
<td>95</td>
<td>0</td>
<td>1</td>
<td>1/4/2012 00:00</td>
<td>1/1/2012 00:00</td>
</tr>
<tr>
<td>9</td>
<td>121</td>
<td>97/488</td>
<td>12/24/2011 00:00</td>
<td>601.95</td>
<td>601.95</td>
<td>0</td>
<td>3</td>
<td>1/24/2012 00:00</td>
<td>1/21/2012 00:00</td>
</tr>
</tbody>
</table>

**Child Data Table – Invoice Line Items**

<table>
<thead>
<tr>
<th>InvoiceID</th>
<th>InvoiceSequence</th>
<th>AccountNo</th>
<th>InvoiceLineItemAmount</th>
<th>InvoiceLineItemDescription</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>553</td>
<td>3813.33</td>
<td>Freight</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>553</td>
<td>40.2</td>
<td>Freight</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>553</td>
<td>138.75</td>
<td>Freight</td>
</tr>
</tbody>
</table>
Appendix: Helpful Cypher commands

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Command</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Get all nodes / relationships</td>
<td><code>start n=node(*) return n</code></td>
<td></td>
</tr>
<tr>
<td>Delete all nodes / relationships</td>
<td><code>MATCH (n) OPTIONAL MATCH (n)-[r]-(l) DELETE n,r;</code></td>
<td><code>New command in Version 2.3 is: MATCH n DETACH DELETE n</code></td>
</tr>
</tbody>
</table>

Appendix: Graph Style Sheet

This allows great customization of the nodes and relationships.

```javascript
node {
  diameter: 75px;
  color: #A5ABB6;
  border-color: #9AA1AC;
  border-width: 2px;
  text-color-internal: #FFFFFF;
  font-size: 10px;
}

relationship {
  color: #A5ABB6;
  shaft-width: 1px;
  font-size: 8px;
  padding: 3px;
  text-color-external: #000000;
```
Appendix – Helpful tips for using Neo4j browser

http://neo4j.com/blog/neo4j-2-0-0-m06-introducing-neo4js-browser/

Just type in a single-line query and hit <enter>. You’ll get a result frame in the stream, showing either a table of property data or a graph visualization of nodes and relationships.

Type another query, get another frame. Tap the up arrow to retrieve a previous entry, edit, and then run it again.

For larger queries, hit <shift-enter> to switch into multi-line editor mode. Now you’ll need to use <ctrl-enter> to run, and <ctrl> up or down arrow to navigate history (the modifier also works in single-line mode).

Finally, and thankfully, you can save scripts. Hit the star button to save the current editor content, which will be available in the sidebar. By convention, the first line can be a comment which will be used as the name of the query. You can even drag-and-drop in scripts, for sharing queries or small-scale data import.

References


Neo4j Cypher Refcard 2.3.1 : http://neo4j.com/docs/stable/cypher-refcard/

Robinson, Ian, and James Webber. Graph Databases: New Opportunities for Connected Data. Second ed.