graphing_notebook_jdh_FINAL

August 5, 2024

1 205: Project 3, Jonathan Hernandez

[1]:
```
import neo4j
import pandas as pd
from IPython.display import display
```

[2]:
```
import matplotlib.pyplot as plt
from neo4j import GraphDatabase # required for graph algorithms
from scipy.cluster.hierarchy import dendrogram, linkage
import seaborn as sns
```

1.1 Remember the Basics

- Calmly, Orderly, Systematically, Logically… reduce the Search Space
- Expect and make peace with frustration and confusion. Both demonstrate stretching ourselves out of our comfort zone, learning at our maximum potential, not limiting ourselves to what is easy to learn.

Nodes (vertices) can have: labels for classification and properties (attributes as key / value pairs)

Relationships (edges) can have: type, direction, and properties (attributes as key / value pairs); Additional Reading: - https://networkx.org/documentation/stable/reference/generated/networkx.drawing.layout.bipartite_layout.html - https://networkx.org/documentation/stable/reference/generated/networkx.drawing.layout.spring_layout.html

Jupyter Hotkeys for VSC Creating Cells

1. Create a Code Cell After the Current Position: • Mac: Option + Enter This hotkey will create a new code cell directly below the currently selected cell and move the cursor to the new cell.

2. Create a Markdown Cell After the Current Position: • Mac: Cmd + Shift + Option + M Alternatively, you can convert an existing code cell to a markdown cell using: •Mac: M (when the cell is in command mode)

Running Cells

1. Run All Cells Above a Certain Point: There isn't a direct hotkey to run all cells above the current point. However, you can accomplish this by: • Command Palette: Cmd + Shift + P (Mac) to open the Command Palette, then type "Run Above" and select "Run Above".

Web server interface at https://xxxx:7473   Username: neo4j

Password: ucb_mids_w205

The above web server allows and interactive GUI which can output graphs visually in addition to table like output. The nodes in the graphs can be moved around with the mouse to make the graphs more readable.

Basics: `:server connect` - connect to the server, username is "neo4j", password is "ucb_mids_w205"

`:server status` - shows that username and server you are logged into

`:clear` - clears off old cells

`show databases` - note that community edition only has 1 application database that we can use neo4j, we cannot create now use other databases, we have to wipe out neo4j database for each new graph

Cypher as the query language:

- analogous to SQL for a relational database; Cypher is open source and like SQL is used for multiple database, Cypher can be used for other graph databases

`()` node

`[]` relationships

`->` `<-` directions, every relationship must have 1 and only 1 direction

`(p:Person)` p is a variable, Person is a node label

`(:Person)` no variable, Person is a node label

`(p:Person {name: 'John', birth_year: 1970})` name is a property of the node with value 'John', and birth_year is a property with value 1970

`(p1:Person {name: 'John'})-[r:IS_FRIEND_OF]->(p2:Person {name: 'Mary'})` r is a variable, IS_FRIEND_OF is a relationship type

`(p1:Person {name: 'John'})-[:IS_FRIEND_OF {since: 1983}]->(p2:Person {name: 'Mary'})` since is a property of the relationship

`match` matches a pattern of nodes and/or relationships

`return` which properties of nodes and/or relationships to return

`order by` sorting just like SQL

`limit` limiting the rows returned just like SQL

`collect` a form of a pivot to turn rows into a list `unwind` a form of an unpivot to turn a list into rows

`create` creates nodes and/or relationships

`delete` deletes nodes and/or relationships

1.1.1 Connect, login, create driver, create session; with community edition, we can only use 1 database, the "neo4j" database

[3]:

```
# driver = neo4j.GraphDatabase.driver(uri="neo4j://<EXTERNAL_IP>:7687", auth=("neo4j", "ucb_mids_w205"))
```

[4]:

```
# driver = neo4j.GraphDatabase.driver(uri="neo4j://neo4j:7687", auth=("neo4j","ucb_mids_w205"))
```

Local -> Cloud access, comment out prior to submitting

[60]:

```
driver = neo4j.GraphDatabase.driver(uri="neo4j://54.156.52.158:7687", auth=("neo4j", "ucb_mids_w205"))
```

[61]:

```
session = driver.session(database="neo4j")
```

2 Function Definitions

2.0.1 Visualize Graph (This is not required for the cells with the core graph creation functions to run*****)

[49]:

```
# PRODUCTION VERSION

# !pip install networkx
# !pip install py2neo
# !pip install scipy
from py2neo import Graph
import networkx as nx
import matplotlib.pyplot as plt

# Function to visualize the graph using networkx
def visualize_graph(title="Neo4j Graph Visualization"):
    # Connect to the Neo4j database
    graph = Graph("bolt://54.156.52.158:7687", auth=("neo4j", "ucb_mids_w205"))

    # Define a query to get nodes and relationships
    query = """
    MATCH (n)-[r]->(m)
    RETURN n.name AS from, type(r) AS type, m.name AS to
    """

    # Run the query
    results = graph.run(query)
    # Create a NetworkX graph
    G = nx.DiGraph()

    # Add nodes and edges to the NetworkX graph
    for record in results:
        G.add_edge(record["from"], record["to"], label=record["type"])

    # Choose a layout algorithm
    # pos = nx.spring_layout(G, k=0.5)  # k controls the distance between nodes␣
↪- CHAOS
    # pos = nx.circular_layout(G) #  DIFFICULT TO WEIGHT
    # pos = nx.shell_layout(G) # BETTER
    pos = nx.kamada_kawai_layout(G, weight=None) #

    # Draw the nodes and edges
    plt.figure(figsize=(12, 8))
    nx.draw_networkx_nodes(G, pos, node_size=500, node_color="lightblue")
    nx.draw_networkx_edges(G, pos, edgelist=G.edges(), arrowstyle='->',␣
↪arrowsize=45)
    nx.draw_networkx_labels(G, pos, font_size=10, font_weight="normal")

    # Draw the edge labels
    edge_labels = nx.get_edge_attributes(G, 'label')
    nx.draw_networkx_edge_labels(G, pos, edge_labels=edge_labels,␣
↪font_color='red')

    # Display the graph
    plt.title(title)
    plt.show()
```

2.0.2 my_neo4j_wipe_out_database()

- since community edition can only have 1 database "neo4j", this function will wipe out all the nodes and relationships

[8]:

```
def my_neo4j_wipe_out_database():
    "wipe out database by deleting all nodes and relationships"

    query = "match (node)-[relationship]->() delete node, relationship"
    session.run(query)

    query = "match (node) delete node"
    session.run(query)
```

2.0.3 my_neo4j_run_query_pandas()

will run a Cypher query and put the results in a Pandas dataframe; easy to see how you can use Python to manipulate the returned data

[9]:

```
def my_neo4j_run_query_pandas(query, **kwargs):
    "run a query and return the results in a pandas dataframe"

    result = session.run(query, **kwargs)

    df = pd.DataFrame([r.values() for r in result], columns=result.keys())

    return df
```

2.0.4 my_neo4j_nodes_relationships()

- will print the nodes (assumes a name property) and relationships

[10]:

```
def my_neo4j_nodes_relationships():
    "print all the nodes and relationships"

    print("-------------------------")
    print("  Nodes:")
    print("-------------------------")

    query = """
        match (n)
        return n.name as node_name, labels(n) as labels
        order by n.name
    """

    df = my_neo4j_run_query_pandas(query)

    number_nodes = df.shape[0]

    display(df)

    print("-------------------------")
    print("  Relationships:")
    print("-------------------------")

    query = """
        match (n1)-[r]->(n2)
        return n1.name as node_name_1, labels(n1) as node_1_labels,
            type(r) as relationship_type, n2.name as node_name_2, labels(n2) as␣
  ↪node_2_labels
        order by node_name_1, node_name_2
    """
```

```
df = my_neo4j_run_query_pandas(query)

number_relationships = df.shape[0]

display(df)

density = (2 * number_relationships) / (number_nodes * (number_nodes - 1))

print("-------------------------")
print("  Density:", f'{density:.1f}')
print("-------------------------")
```

---

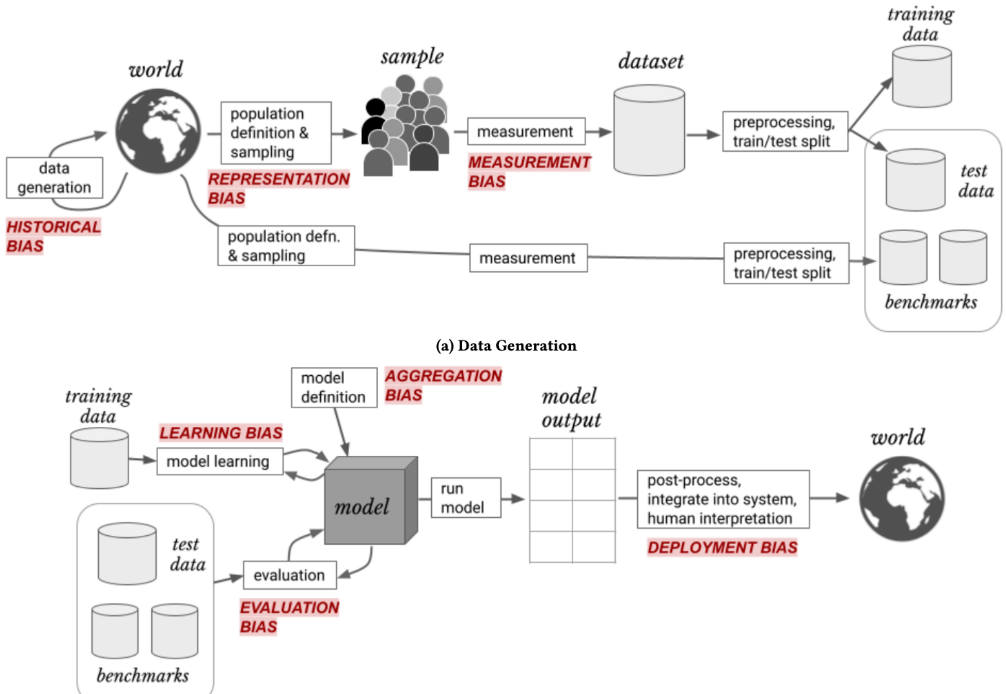
3 Project Three Coding Submission, By Jonathan Hernandez

This project was inspired by Unit 12 of DATASCI 207, Applied Machine Learning, and the paper, ‘A Framework for Understanding Sources of Harm throughout the Machine Learning Life Cycle’ by Suresh and Guttag, 2021.

These graphs look at two things: - 1. The Machine Learning Workflow, its Nodes, Processes, and Biases - 2. A Fictitious Future Structure of a company known as OpenAI. This structure takes place in 2034, after launching a fictiious subsidiary called OpenAI Web Services (OWS), loosely inspired by my experience working at AWS.

There are four graphs, relating two Sets of Nodes, gradually increasing complexity, and three submission-worthy graph algorithms, one extra is included at the end.

The algorithms are only run on the final version of the graph, and the first three versions are merely illustrative.



(a) Data Generation

(b) Model Building and Implementation

Figure 1: (a) The data generation process begins with data collection. This process involves defining a target population and sampling from it, as well as identifying and measuring features and labels. This dataset is split into training and test sets. Data is also collected (perhaps by a different process) into benchmark datasets. (b) A model is defined, and optimized on the training data. Test and benchmark data is used to evaluate it, and the final model is then integrated into a real-world context. This process is naturally cyclic, and decisions influenced by models affect the state of the world that exists the next time data is collected or decisions are applied. In red, we indicate where in this pipeline different sources of downstream harm might arise.

3.1 Graph 1: Set A: Machine Learning Workflow with Bias Nodes

[41]:

```
my_neo4j_wipe_out_database()

query = """
CREATE
  (a0:ML_Workflow {name: 'World', bias: 'Historical Bias'}), //
  (a00:PROCESS {name: 'Data Generation'}),
  (a01:PROCESS {name: 'Population Definition & Sampling'}),
  (a000:BIAS {name: 'Historical Bias'}),
  (a1:ML_Workflow {name: 'Sample'}), //
  (a10:PROCESS {name: 'Measurement'}),
  (a100:BIAS {name: 'Representation Bias'}),
  (a2:ML_Workflow {name: 'Dataset'}), //
  (a20:PROCESS {name: 'Preprocessing, Train/Test Split'}),
  (a200:BIAS {name: 'Measurement Bias'}),
  (a3:ML_Workflow {name: 'Training Data'}), //
  (a30:PROCESS {name: 'Model Learning'}),
  (a300:BIAS {name: 'Learning Bias'}),
  (a4:ML_Workflow {name: 'Test Data'}), //
```

```
(a40:PROCESS {name: 'Evaluation'}),
(a400:BIAS {name: 'Evaluation Bias'}),
(a5:ML_Workflow {name: 'Benchmarks'}), // feeds evaluation
(a60:PROCESS {name: 'Model Definition'}), //  feeds model
(a600:BIAS {name: 'Aggregation Bias'}),
(a7:ML_Workflow {name: 'Model'}), // feeds model output
(a70:PROCESS {name: 'Run Model'}),
(a8:ML_Workflow {name: 'Model Output'}), //
(a80:PROCESS {name: 'Post-Process'}),
(a81:PROCESS {name: 'Integrate into Systems'}),
(a82:PROCESS {name: 'Human & Model Interaction'}),
(a800:BIAS {name: 'Deployment Bias'}),

(a0)-[:FEEDS]->(a00), //
(a0)-[:FEEDS]->(a01), //
(a00)-[:FEEDS]->(a0),
(a01)-[:FEEDS]->(a1),
(a000)-[:BIASES]->(a0),
(a000)-[:BIASES]->(a00),
(a1)-[:FEEDS]->(a10), //
(a10)-[:FEEDS]->(a2),
(a100)-[:BIASES]->(a01),
(a100)-[:BIASES]->(a1),
(a2)-[:FEEDS]->(a20), //
(a20)-[:FEEDS]->(a3),
(a20)-[:FEEDS]->(a4),
(a200)-[:BIASES]->(a10),
(a200)-[:BIASES]->(a2),
(a200)-[:BIASES]->(a20),
(a30)-[:FEEDS]->(a7), //
(a7)-[:FEEDS]->(a30),
(a3)-[:FEEDS]->(a30),
(a300)-[:BIASES]->(a3),
(a300)-[:BIASES]->(a30),
(a300)-[:BIASES]->(a7),
(a4)-[:FEEDS]->(a40), //
(a40)-[:FEEDS]->(a7),
(a400)-[:BIASES]->(a4),
(a400)-[:BIASES]->(a40),
(a400)-[:BIASES]->(a5),
(a400)-[:BIASES]->(a7),
(a5)-[:FEEDS]->(a40), //
(a60)-[:FEEDS]->(a7), //
(a600)-[:BIASES]->(a60),
(a600)-[:BIASES]->(a7),
(a7)-[:FEEDS]->(a70), //
(a70)-[:FEEDS]->(a8),
  (a8)-[:FEEDS]->(a80), //
  (a8)-[:FEEDS]->(a81),
  (a8)-[:FEEDS]->(a82),
  (a80)-[:FEEDS]->(a0),
  (a81)-[:FEEDS]->(a0),
  (a82)-[:FEEDS]->(a0),
  (a800)-[:BIASES]->(a8),
  (a800)-[:BIASES]->(a70),
  (a800)-[:BIASES]->(a80),
  (a800)-[:BIASES]->(a81),
  (a800)-[:BIASES]->(a82),
  (a800)-[:BIASES]->(a0),

// link population definition and sampling, measurement, preprocessing tran/
 ↪test split, and benchmarks
  (a01)-[:FEEDS]->(a10),
  (a10)-[:FEEDS]->(a20),
  (a20)-[:FEEDS]->(a5)

"""

session.run(query)
```

```
[41]: <neo4j._sync.work.result.Result at 0x17780b4c0>
```

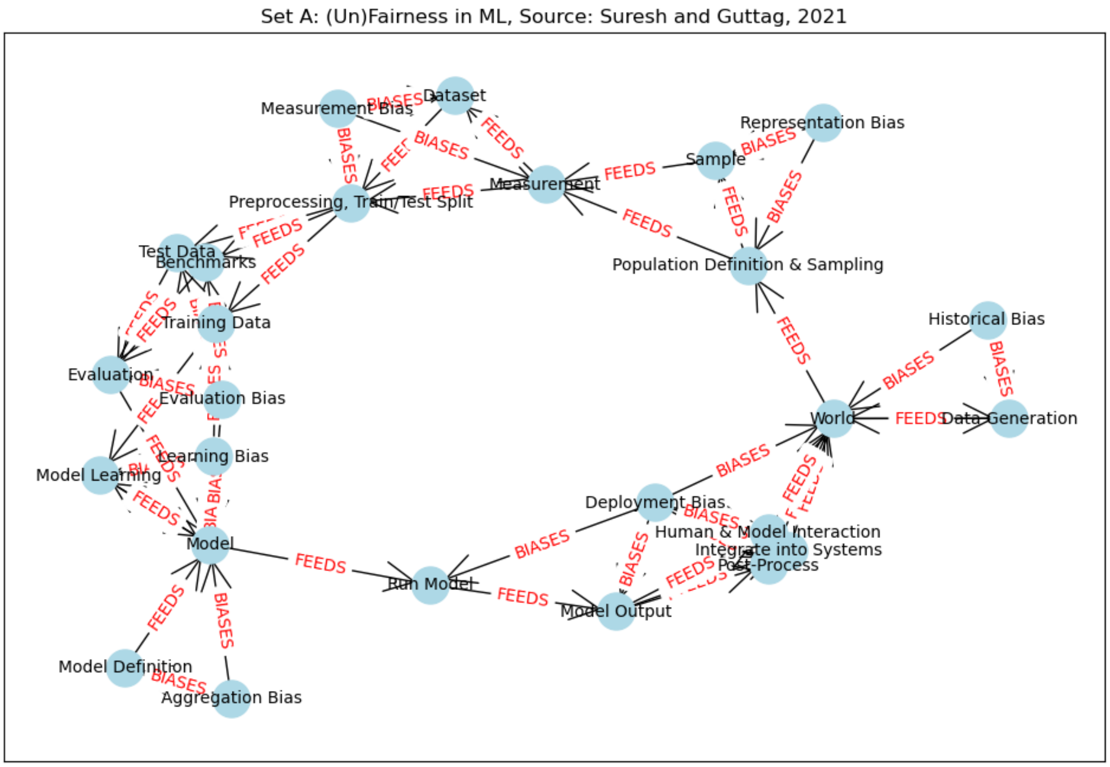
```
[43]: my_neo4j_nodes_relationships()
      visualize_graph('Set A: (Un)Fairness in ML, Source: Suresh and Guttag, 2021')
```

```
-------------------------
  Nodes:
-------------------------

                        node_name         labels
0                 Aggregation Bias          [BIAS]
1                       Benchmarks   [ML_Workflow]
2                  Data Generation       [PROCESS]
3                          Dataset   [ML_Workflow]
4                  Deployment Bias          [BIAS]
5                       Evaluation       [PROCESS]
6                  Evaluation Bias          [BIAS]
7                  Historical Bias          [BIAS]
8          Human & Model Interaction       [PROCESS]
9           Integrate into Systems       [PROCESS]
10                   Learning Bias          [BIAS]
11                     Measurement       [PROCESS]
12                Measurement Bias          [BIAS]
13                           Model   [ML_Workflow]
14                Model Definition       [PROCESS]
```

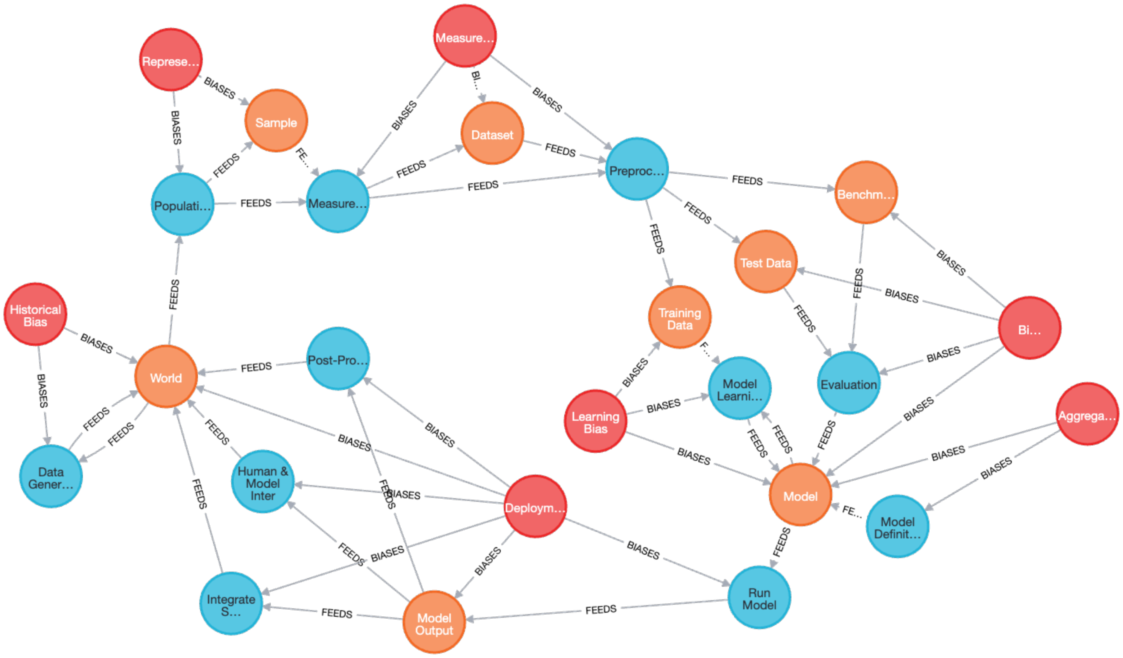
```
15                    Model Learning      [PROCESS]
16                      Model Output  [ML_Workflow]
17  Population Definition & Sampling      [PROCESS]
18                      Post-Process      [PROCESS]
19   Preprocessing, Train/Test Split      [PROCESS]
20               Representation Bias         [BIAS]
21                         Run Model      [PROCESS]
22                            Sample  [ML_Workflow]
23                         Test Data  [ML_Workflow]
24                     Training Data  [ML_Workflow]
25                             World  [ML_Workflow]

-------------------------
  Relationships:
-------------------------

                         node_name_1  node_1_labels relationship_type  \
0                   Aggregation Bias         [BIAS]            BIASES
1                   Aggregation Bias         [BIAS]            BIASES
2                         Benchmarks  [ML_Workflow]             FEEDS
3                    Data Generation      [PROCESS]             FEEDS
4                            Dataset  [ML_Workflow]             FEEDS
5                    Deployment Bias         [BIAS]            BIASES
6                    Deployment Bias         [BIAS]            BIASES
7                    Deployment Bias         [BIAS]            BIASES
8                    Deployment Bias         [BIAS]            BIASES
9                    Deployment Bias         [BIAS]            BIASES
10                   Deployment Bias         [BIAS]            BIASES
11                        Evaluation      [PROCESS]             FEEDS
12                   Evaluation Bias         [BIAS]            BIASES
13                   Evaluation Bias         [BIAS]            BIASES
14                   Evaluation Bias         [BIAS]            BIASES
15                   Evaluation Bias         [BIAS]            BIASES
16                   Historical Bias         [BIAS]            BIASES
17                   Historical Bias         [BIAS]            BIASES
18         Human & Model Interaction      [PROCESS]             FEEDS
19            Integrate into Systems      [PROCESS]             FEEDS
20                     Learning Bias         [BIAS]            BIASES
21                     Learning Bias         [BIAS]            BIASES
22                     Learning Bias         [BIAS]            BIASES
23                       Measurement      [PROCESS]             FEEDS
24                       Measurement      [PROCESS]             FEEDS
25                  Measurement Bias         [BIAS]            BIASES
26                  Measurement Bias         [BIAS]            BIASES
27                  Measurement Bias         [BIAS]            BIASES
28                             Model  [ML_Workflow]             FEEDS
29                             Model  [ML_Workflow]             FEEDS
30                  Model Definition      [PROCESS]             FEEDS
31                    Model Learning      [PROCESS]             FEEDS
```

```
32                      Model Output  [ML_Workflow]             FEEDS
33                      Model Output  [ML_Workflow]             FEEDS
34                      Model Output  [ML_Workflow]             FEEDS
35  Population Definition & Sampling      [PROCESS]             FEEDS
36  Population Definition & Sampling      [PROCESS]             FEEDS
37                      Post-Process      [PROCESS]             FEEDS
38   Preprocessing, Train/Test Split      [PROCESS]             FEEDS
39   Preprocessing, Train/Test Split      [PROCESS]             FEEDS
40   Preprocessing, Train/Test Split      [PROCESS]             FEEDS
41               Representation Bias         [BIAS]            BIASES
42               Representation Bias         [BIAS]            BIASES
43                         Run Model      [PROCESS]             FEEDS
44                            Sample  [ML_Workflow]             FEEDS
45                         Test Data  [ML_Workflow]             FEEDS
46                     Training Data  [ML_Workflow]             FEEDS
47                             World  [ML_Workflow]             FEEDS
48                             World  [ML_Workflow]             FEEDS

                         node_name_2  node_2_labels
0                              Model  [ML_Workflow]
1                   Model Definition      [PROCESS]
2                         Evaluation      [PROCESS]
3                              World  [ML_Workflow]
4    Preprocessing, Train/Test Split      [PROCESS]
5          Human & Model Interaction      [PROCESS]
6             Integrate into Systems      [PROCESS]
7                       Model Output  [ML_Workflow]
8                       Post-Process      [PROCESS]
9                          Run Model      [PROCESS]
10                             World  [ML_Workflow]
11                             Model  [ML_Workflow]
12                        Benchmarks  [ML_Workflow]
13                        Evaluation      [PROCESS]
14                             Model  [ML_Workflow]
15                         Test Data  [ML_Workflow]
16                   Data Generation      [PROCESS]
17                             World  [ML_Workflow]
18                             World  [ML_Workflow]
19                             World  [ML_Workflow]
20                             Model  [ML_Workflow]
21                    Model Learning      [PROCESS]
22                     Training Data  [ML_Workflow]
23                           Dataset  [ML_Workflow]
24   Preprocessing, Train/Test Split      [PROCESS]
25                           Dataset  [ML_Workflow]
26                       Measurement      [PROCESS]
27   Preprocessing, Train/Test Split      [PROCESS]
28                    Model Learning      [PROCESS]
```

```
29                         Run Model      [PROCESS]
30                             Model  [ML_Workflow]
31                             Model  [ML_Workflow]
32          Human & Model Interaction      [PROCESS]
33             Integrate into Systems      [PROCESS]
34                       Post-Process      [PROCESS]
35                        Measurement      [PROCESS]
36                            Sample  [ML_Workflow]
37                             World  [ML_Workflow]
38                         Benchmarks  [ML_Workflow]
39                          Test Data  [ML_Workflow]
40                      Training Data  [ML_Workflow]
41  Population Definition & Sampling      [PROCESS]
42                            Sample  [ML_Workflow]
43                       Model Output  [ML_Workflow]
44                        Measurement      [PROCESS]
45                         Evaluation      [PROCESS]
46                     Model Learning      [PROCESS]
47                    Data Generation      [PROCESS]
48  Population Definition & Sampling      [PROCESS]

-------------------------
  Density: 0.2
-------------------------
```



Set A: (Un)Fairness in ML, Source: Suresh and Guttag, 2021



3.2 Graph 2: Set C: Company Set of Nodes

Define the nodes, then define the relationships

[26]:

```
my_neo4j_wipe_out_database()

query = """
CREATE
  // Source: Fictitious
  (c0:Company {name: 'OpenAI, Inc.'}),
  (c00:Company {name: 'OpenAI Global, LLC.'}),
  (c1:Company {name: 'OpenAI Web Services'}),
  (c2:Company {name: 'Manufacturing'}),
  (c3:Company {name: 'Energy'}),
  (c4:Company {name: 'Mining and Extraction'}),
  (c5:Company {name: 'Financial Services'}),
  (c6:Company {name: 'Healthcare'}),
  (c7:Company {name: 'Education'}),
  (c8:Company {name: 'Real Estate'}),
  (c9:Company {name: 'Information Technology'}),
  (c10:Company {name: 'Biotechnology'}),
  (c11:Company {name: 'Telecommunications'}),
  (c12:Company {name: 'Consumer Goods and Services'}),
  (c13:Company {name: 'Transportation and Logistics'}),
  (c14:Company {name: 'Media and Communications'}),
  (c15:Company {name: 'Infrastructure'}),
  (c16:Company {name: 'Financial Markets'}),
  (c17:Company {name: 'Business Services'}),
  (c18:Company {name: 'Research and Development'}),
  (c19:Company {name: 'Government'}),
  (c20:Company {name: 'Intelligence'}),
  (c21:Company {name: 'Military'}),

  (c0)-[:IS_PARENT_OF {since: 1984}]->(c00),
  (c00)-[:IS_PARENT_OF]->(c1),
  (c1)-[:IS_PARENT_OF]->(c2),
  (c1)-[:IS_PARENT_OF]->(c3),
  (c1)-[:IS_PARENT_OF]->(c4),
  (c1)-[:IS_PARENT_OF]->(c5),
  (c1)-[:IS_PARENT_OF]->(c6),
  (c1)-[:IS_PARENT_OF]->(c7),
  (c1)-[:IS_PARENT_OF]->(c8),
  (c1)-[:IS_PARENT_OF]->(c9),
  (c1)-[:IS_PARENT_OF]->(c10),
  (c1)-[:IS_PARENT_OF]->(c11),
  (c1)-[:IS_PARENT_OF]->(c12),
  (c1)-[:IS_PARENT_OF]->(c13),
  (c1)-[:IS_PARENT_OF]->(c14),
  (c1)-[:IS_PARENT_OF]->(c15),
  (c1)-[:IS_PARENT_OF]->(c16),
  (c1)-[:IS_PARENT_OF]->(c17),
  (c1)-[:IS_PARENT_OF]->(c18),
  (c1)-[:IS_PARENT_OF]->(c19),
  (c1)-[:IS_PARENT_OF]->(c20),
  (c1)-[:IS_PARENT_OF]->(c21)

"""

session.run(query)
```

[26]:

```
<neo4j._sync.work.result.Result at 0x17602a200>
```

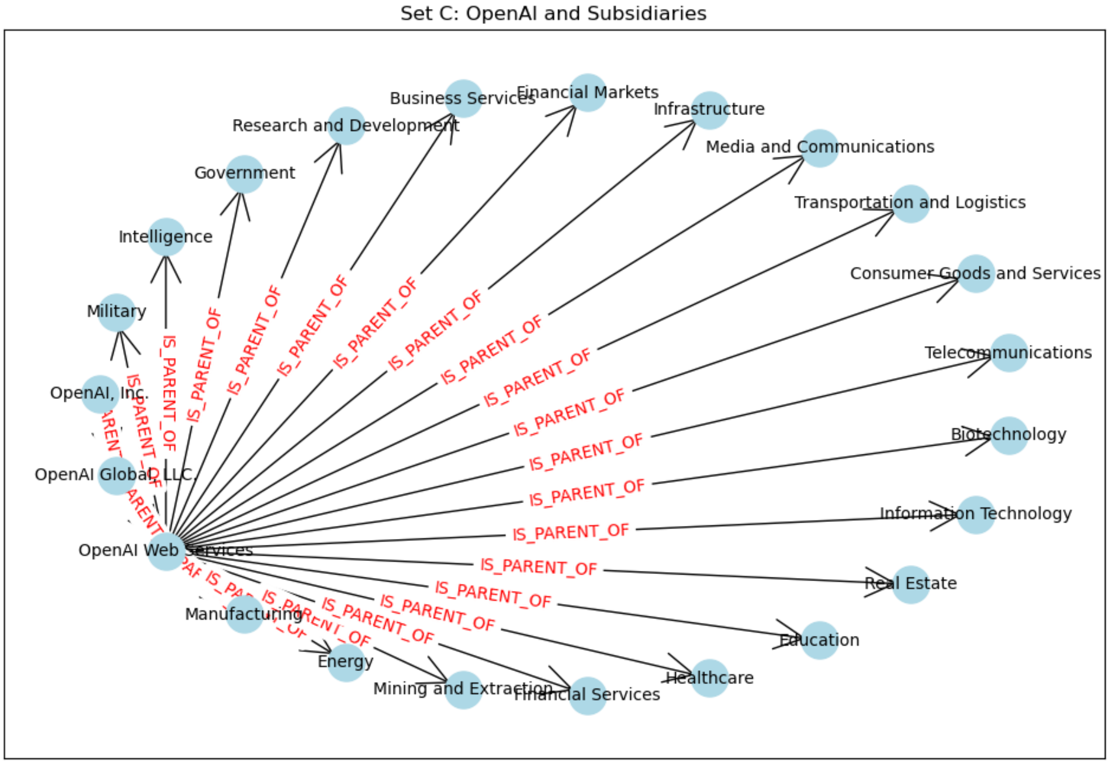
[27]:

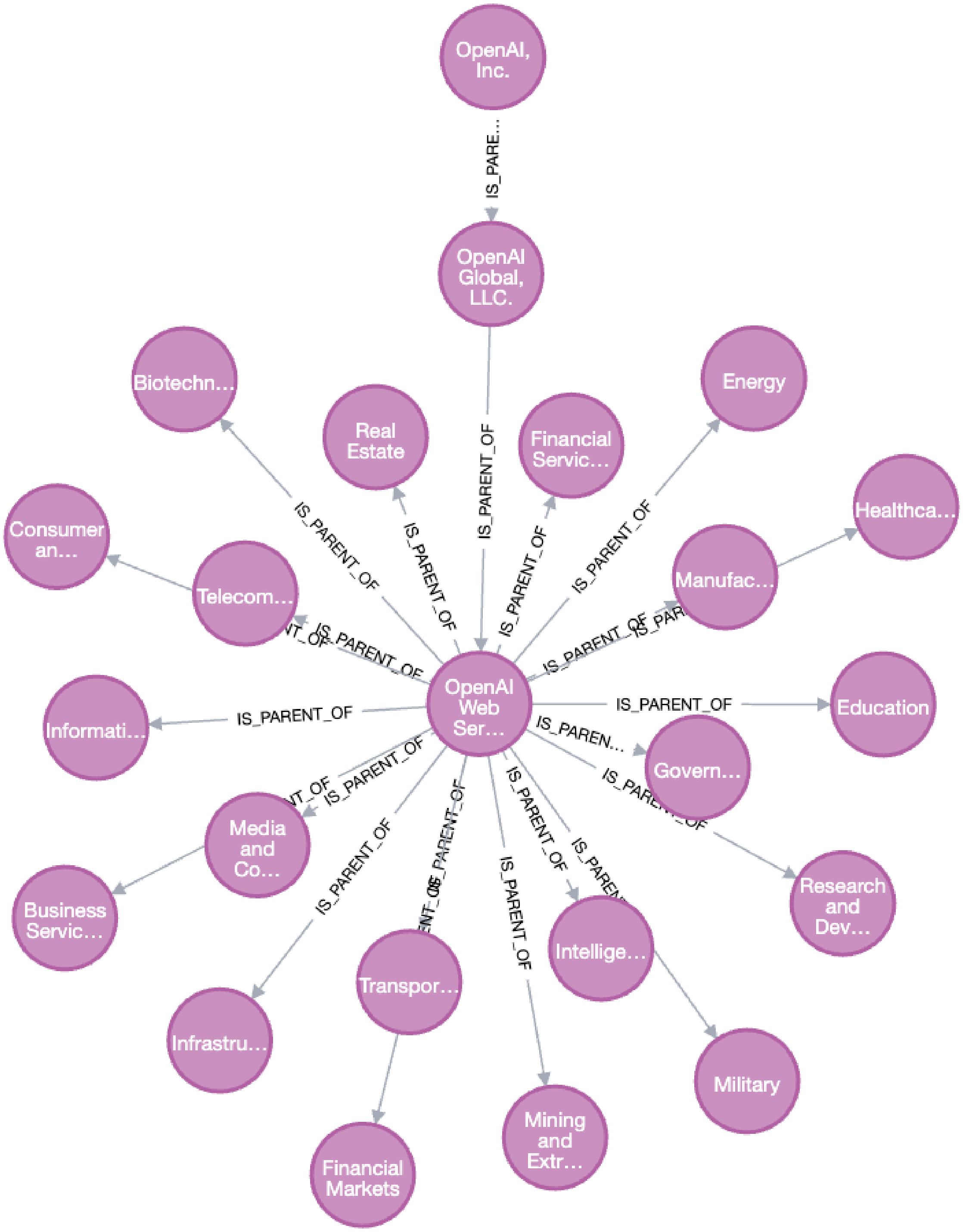
```
my_neo4j_nodes_relationships()
visualize_graph('Set C: OpenAI and Subsidiaries')
```

```
-------------------------
  Nodes:
-------------------------

                       node_name     labels
0                  Biotechnology  [Company]
1              Business Services  [Company]
2    Consumer Goods and Services  [Company]
3                      Education  [Company]
4                         Energy  [Company]
```

```
5              Financial Markets  [Company]
6             Financial Services  [Company]
7                     Government  [Company]
8                     Healthcare  [Company]
9         Information Technology  [Company]
10                Infrastructure  [Company]
11                  Intelligence  [Company]
12                 Manufacturing  [Company]
13      Media and Communications  [Company]
14                      Military  [Company]
15         Mining and Extraction  [Company]
16           OpenAI Global, LLC.  [Company]
17           OpenAI Web Services  [Company]
18                  OpenAI, Inc.  [Company]
19                   Real Estate  [Company]
20      Research and Development  [Company]
21            Telecommunications  [Company]
22  Transportation and Logistics  [Company]

-------------------------
  Relationships:
-------------------------

            node_name_1 node_1_labels relationship_type  \
0   OpenAI Global, LLC.     [Company]      IS_PARENT_OF
1   OpenAI Web Services     [Company]      IS_PARENT_OF
2   OpenAI Web Services     [Company]      IS_PARENT_OF
3   OpenAI Web Services     [Company]      IS_PARENT_OF
4   OpenAI Web Services     [Company]      IS_PARENT_OF
5   OpenAI Web Services     [Company]      IS_PARENT_OF
6   OpenAI Web Services     [Company]      IS_PARENT_OF
7   OpenAI Web Services     [Company]      IS_PARENT_OF
8   OpenAI Web Services     [Company]      IS_PARENT_OF
9   OpenAI Web Services     [Company]      IS_PARENT_OF
10  OpenAI Web Services     [Company]      IS_PARENT_OF
11  OpenAI Web Services     [Company]      IS_PARENT_OF
12  OpenAI Web Services     [Company]      IS_PARENT_OF
13  OpenAI Web Services     [Company]      IS_PARENT_OF
14  OpenAI Web Services     [Company]      IS_PARENT_OF
15  OpenAI Web Services     [Company]      IS_PARENT_OF
16  OpenAI Web Services     [Company]      IS_PARENT_OF
17  OpenAI Web Services     [Company]      IS_PARENT_OF
18  OpenAI Web Services     [Company]      IS_PARENT_OF
19  OpenAI Web Services     [Company]      IS_PARENT_OF
20  OpenAI Web Services     [Company]      IS_PARENT_OF
21         OpenAI, Inc.     [Company]      IS_PARENT_OF

                     node_name_2 node_2_labels
0            OpenAI Web Services     [Company]
```

```
1                 Biotechnology     [Company]
2             Business Services     [Company]
3   Consumer Goods and Services     [Company]
4                     Education     [Company]
5                        Energy     [Company]
6             Financial Markets     [Company]
7            Financial Services     [Company]
8                    Government     [Company]
9                    Healthcare     [Company]
10       Information Technology     [Company]
11               Infrastructure     [Company]
12                 Intelligence     [Company]
13                Manufacturing     [Company]
14     Media and Communications     [Company]
15                     Military     [Company]
16        Mining and Extraction     [Company]
17                  Real Estate     [Company]
18     Research and Development     [Company]
19           Telecommunications     [Company]
20  Transportation and Logistics    [Company]
21           OpenAI Global, LLC.    [Company]

-------------------------
  Density: 0.1
-------------------------
```


Set C: OpenAI and Subsidiaries



3.3 Graph 3: Set A & C: Ownership / Relational Model

Notation Guide: - 1 digit: ML_Workflow or Company Node - 2 digits: PROCESS - 3 digits: bias

```
[29]: my_neo4j_wipe_out_database()

      query = """
      CREATE

        // Source: Fictitious
        (c0:Company {name: 'OpenAI, Inc.'}),
        (c00:Company {name: 'OpenAI Global, LLC.'}),
        (c1:Company {name: 'OpenAI Web Services'}),
        (c2:Company {name: 'Manufacturing'}),
        (c3:Company {name: 'Energy'}),
        (c4:Company {name: 'Mining and Extraction'}),
        (c5:Company {name: 'Financial Services'}),
        (c6:Company {name: 'Healthcare'}),
        (c7:Company {name: 'Education'}),
        (c8:Company {name: 'Real Estate'}),
        (c9:Company {name: 'Information Technology'}),
        (c10:Company {name: 'Biotechnology'}),
        (c11:Company {name: 'Telecommunications'}),
        (c12:Company {name: 'Consumer Goods and Services'}),
        (c13:Company {name: 'Transportation and Logistics'}),
        (c14:Company {name: 'Media and Communications'}),
        (c15:Company {name: 'Infrastructure'}),
        (c16:Company {name: 'Financial Markets'}),
        (c17:Company {name: 'Business Services'}),
        (c18:Company {name: 'Research and Development'}),
        (c19:Company {name: 'Government'}),
        (c20:Company {name: 'Intelligence'}),
        (c21:Company {name: 'Military'}),

        // Source: Suresh and Guttag. A Framework for Understanding Sources of Harm␣
       ↪throughout the Machine Learning Lifecycle. 2021.
        (a0:ML_Workflow {name: 'World', bias: 'Historical Bias'}), //
        (a00:PROCESS {name: 'Data Generation'}),
        (a01:PROCESS {name: 'Population Definition & Sampling'}),
        (a000:BIAS {name: 'Historical Bias'}),
        (a1:ML_Workflow {name: 'Sample'}), //
        (a10:PROCESS {name: 'Measurement'}),
        (a100:BIAS {name: 'Representation Bias'}),
        (a2:ML_Workflow {name: 'Dataset'}), //
        (a20:PROCESS {name: 'Preprocessing, Train/Test Split'}),
        (a200:BIAS {name: 'Measurement Bias'}),
        (a3:ML_Workflow {name: 'Training Data'}), //
        (a30:PROCESS {name: 'Model Learning'}),
        (a300:BIAS {name: 'Learning Bias'}),
        (a4:ML_Workflow {name: 'Test Data'}), //
        (a40:PROCESS {name: 'Evaluation'}),
(a400:BIAS {name: 'Evaluation Bias'}),
(a5:ML_Workflow {name: 'Benchmarks'}), // feeds evaluation
(a60:PROCESS {name: 'Model Definition'}), //  feeds model
(a600:BIAS {name: 'Aggregation Bias'}),
(a7:ML_Workflow {name: 'Model'}), // feeds model output
(a70:PROCESS {name: 'Run Model'}),
(a8:ML_Workflow {name: 'Model Output'}), //
(a80:PROCESS {name: 'Post-Process'}),
(a81:PROCESS {name: 'Integrate into Systems'}),
(a82:PROCESS {name: 'Human & Model Interaction'}),
(a800:BIAS {name: 'Deployment Bias'}),

(c0)-[:IS_PARENT_OF {since: 1984}]->(c00),
(c00)-[:IS_PARENT_OF]->(c1),
(c1)-[:IS_PARENT_OF]->(c2),
(c1)-[:IS_PARENT_OF]->(c3),
(c1)-[:IS_PARENT_OF]->(c4),
(c1)-[:IS_PARENT_OF]->(c5),
(c1)-[:IS_PARENT_OF]->(c6),
(c1)-[:IS_PARENT_OF]->(c7),
(c1)-[:IS_PARENT_OF]->(c8),
(c1)-[:IS_PARENT_OF]->(c9),
(c1)-[:IS_PARENT_OF]->(c10),
(c1)-[:IS_PARENT_OF]->(c11),
(c1)-[:IS_PARENT_OF]->(c12),
(c1)-[:IS_PARENT_OF]->(c13),
(c1)-[:IS_PARENT_OF]->(c14),
(c1)-[:IS_PARENT_OF]->(c15),
(c1)-[:IS_PARENT_OF]->(c16),
(c1)-[:IS_PARENT_OF]->(c17),
(c1)-[:IS_PARENT_OF]->(c18),
(c1)-[:IS_PARENT_OF]->(c19),
(c1)-[:IS_PARENT_OF]->(c20),
(c1)-[:IS_PARENT_OF]->(c21),

(a0)-[:FEEDS]->(a00), //
(a0)-[:FEEDS]->(a01), //
(a00)-[:FEEDS]->(a0),
(a01)-[:FEEDS]->(a1),
(a000)-[:BIASES]->(a0),
(a000)-[:BIASES]->(a00),
(a1)-[:FEEDS]->(a10), //
(a10)-[:FEEDS]->(a2),
(a100)-[:BIASES]->(a01),
(a100)-[:BIASES]->(a1),
(a2)-[:FEEDS]->(a20), //
(a20)-[:FEEDS]->(a3),
  (a20)-[:FEEDS]->(a4),
  (a200)-[:BIASES]->(a10),
  (a200)-[:BIASES]->(a2),
  (a200)-[:BIASES]->(a20),
  (a30)-[:FEEDS]->(a7), //
  (a7)-[:FEEDS]->(a30),
  (a3)-[:FEEDS]->(a30),
  (a300)-[:BIASES]->(a3),
  (a300)-[:BIASES]->(a30),
  (a300)-[:BIASES]->(a7),
  (a4)-[:FEEDS]->(a40), //
  (a40)-[:FEEDS]->(a7),
  (a400)-[:BIASES]->(a4),
  (a400)-[:BIASES]->(a40),
  (a400)-[:BIASES]->(a5),
  (a400)-[:BIASES]->(a7),
  (a5)-[:FEEDS]->(a40), //
  (a60)-[:FEEDS]->(a7), //
  (a600)-[:BIASES]->(a60),
  (a600)-[:BIASES]->(a7),
  (a7)-[:FEEDS]->(a70), //
  (a70)-[:FEEDS]->(a8),
  (a8)-[:FEEDS]->(a80), //
  (a8)-[:FEEDS]->(a81),
  (a8)-[:FEEDS]->(a82),
  (a80)-[:FEEDS]->(a0),
  (a81)-[:FEEDS]->(a0),
  (a82)-[:FEEDS]->(a0),
  (a800)-[:BIASES]->(a8),
  (a800)-[:BIASES]->(a70),
  (a800)-[:BIASES]->(a80),
  (a800)-[:BIASES]->(a81),
  (a800)-[:BIASES]->(a82),
  (a800)-[:BIASES]->(a0),

  // link population definition and sampling, measurement, preprocessing tran/test split, and benchmarks
  (a01)-[:FEEDS]->(a10),
  (a10)-[:FEEDS]->(a20),
  (a20)-[:FEEDS]->(a5),

// Linking Sets A and C
  (a7)-[:FEEDS]->(c00), // Model feeds OpenAI Global
  (c00)-[:IS_PARENT_OF]->(a7) // OpenAI Global owns the Model

"""
```

```python
session.run(query)
```

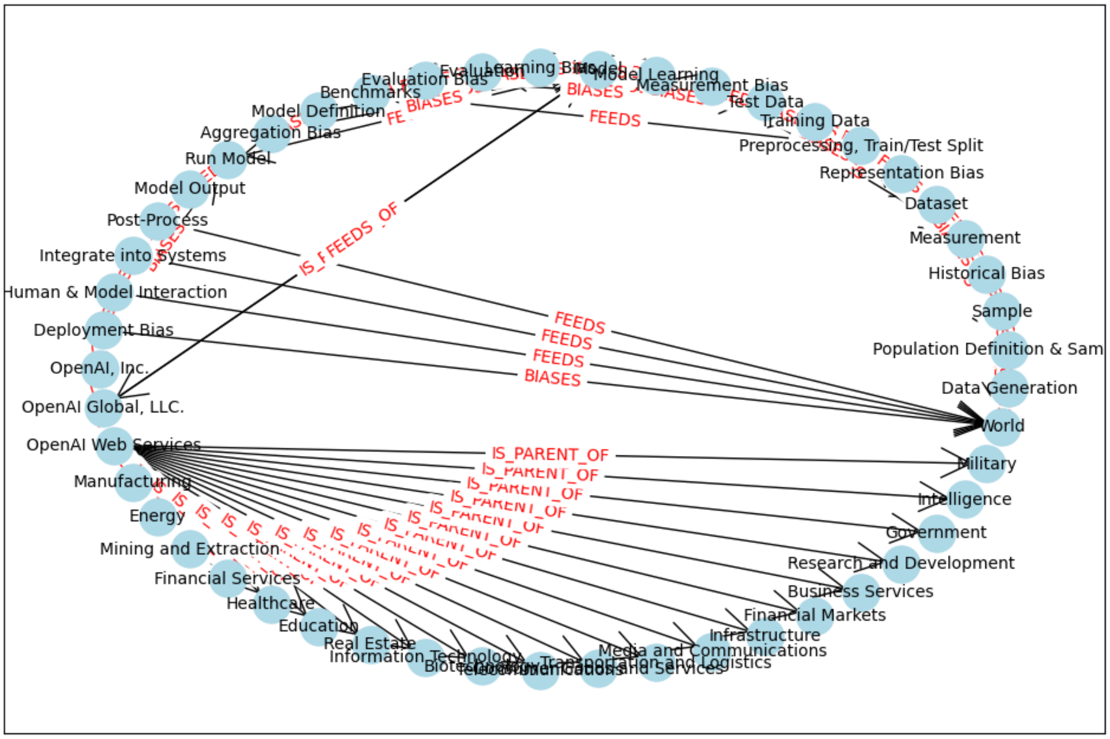
[29]:
```
<neo4j._sync.work.result.Result at 0x175ff4e80>
```

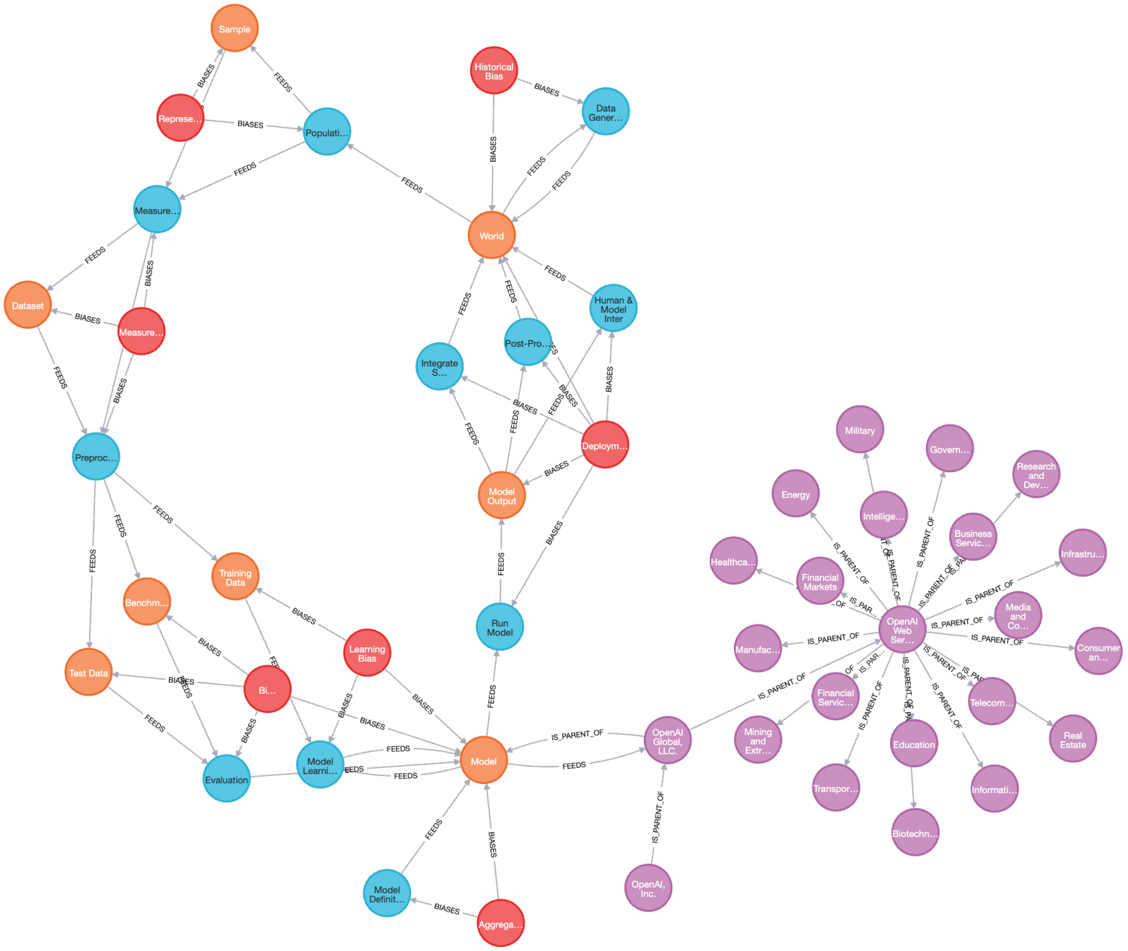
[38]:
```python
my_neo4j_nodes_relationships()
visualize_graph('Sets A & C: OpenAI and Subsidiaries (Relational Model)')
```

```
-------------------------
  Nodes:
-------------------------

                           node_name         labels
0                   Aggregation Bias         [BIAS]
1                         Benchmarks  [ML_Workflow]
2                      Biotechnology      [Company]
3                  Business Services      [Company]
4        Consumer Goods and Services      [Company]
5                    Data Generation      [PROCESS]
6                            Dataset  [ML_Workflow]
7                    Deployment Bias         [BIAS]
8                          Education      [Company]
9                             Energy      [Company]
10                        Evaluation      [PROCESS]
11                   Evaluation Bias         [BIAS]
12                 Financial Markets      [Company]
13                Financial Services      [Company]
14                        Government      [Company]
15                        Healthcare      [Company]
16                   Historical Bias         [BIAS]
17         Human & Model Interaction      [PROCESS]
18            Information Technology      [Company]
19                    Infrastructure      [Company]
20            Integrate into Systems      [PROCESS]
21                      Intelligence      [Company]
22                     Learning Bias         [BIAS]
23                     Manufacturing      [Company]
24                       Measurement      [PROCESS]
25                  Measurement Bias         [BIAS]
26          Media and Communications      [Company]
27                          Military      [Company]
28             Mining and Extraction      [Company]
29                             Model  [ML_Workflow]
30                  Model Definition      [PROCESS]
31                    Model Learning      [PROCESS]
32                      Model Output  [ML_Workflow]
33               OpenAI Global, LLC.      [Company]
34               OpenAI Web Services      [Company]
35                      OpenAI, Inc.      [Company]
```

```
36  Population Definition & Sampling      [PROCESS]
37                      Post-Process      [PROCESS]
38   Preprocessing, Train/Test Split      [PROCESS]
39                       Real Estate      [Company]
40               Representation Bias         [BIAS]
41          Research and Development      [Company]
42                         Run Model      [PROCESS]
43                            Sample  [ML_Workflow]
44                Telecommunications      [Company]
45                         Test Data  [ML_Workflow]
46                     Training Data  [ML_Workflow]
47      Transportation and Logistics      [Company]
48                             World  [ML_Workflow]

-------------------------
  Relationships:
-------------------------

         node_name_1  node_1_labels relationship_type  \
0   Aggregation Bias         [BIAS]            BIASES
1   Aggregation Bias         [BIAS]            BIASES
2         Benchmarks  [ML_Workflow]             FEEDS
3    Data Generation      [PROCESS]             FEEDS
4            Dataset  [ML_Workflow]             FEEDS
..                 …            …                …
68            Sample  [ML_Workflow]             FEEDS
69         Test Data  [ML_Workflow]             FEEDS
70     Training Data  [ML_Workflow]             FEEDS
71             World  [ML_Workflow]             FEEDS
72             World  [ML_Workflow]             FEEDS

                         node_name_2  node_2_labels
0                              Model  [ML_Workflow]
1                   Model Definition      [PROCESS]
2                         Evaluation      [PROCESS]
3                              World  [ML_Workflow]
4    Preprocessing, Train/Test Split      [PROCESS]
..                                 …              …
68                       Measurement      [PROCESS]
69                        Evaluation      [PROCESS]
70                    Model Learning      [PROCESS]
71                   Data Generation      [PROCESS]
72  Population Definition & Sampling      [PROCESS]

[73 rows x 5 columns]

-------------------------
  Density: 0.1
-------------------------
```

Sets A & C: OpenAI and Subsidiaries (Relational Model)





3.4 Graph 4: Set A & C:Operational Realistic Model

Notation Guide: - 1 digit: ML_Workflow or Company Node - 2 digits: PROCESS - 3 digits: bias

[63]:
```
my_neo4j_wipe_out_database()

query = """
CREATE

  // Source: Fictitious
  (c0:Company {name: 'OpenAI, Inc.'}),
  (c00:Company {name: 'OpenAI Global, LLC.'}),
  (c1:Company {name: 'OpenAI Web Services'}),
  (c2:Company {name: 'Manufacturing'}),
  (c3:Company {name: 'Energy'}),
  (c4:Company {name: 'Mining and Extraction'}),
  (c5:Company {name: 'Financial Services'}),
  (c6:Company {name: 'Healthcare'}),
  (c7:Company {name: 'Education'}),
  (c8:Company {name: 'Real Estate'}),
(c9:Company {name: 'Information Technology'}),
(c10:Company {name: 'Biotechnology'}),
(c11:Company {name: 'Telecommunications'}),
(c12:Company {name: 'Consumer Goods and Services'}),
(c13:Company {name: 'Transportation and Logistics'}),
(c14:Company {name: 'Media and Communications'}),
(c15:Company {name: 'Infrastructure'}),
(c16:Company {name: 'Financial Markets'}),
(c17:Company {name: 'Business Services'}),
(c18:Company {name: 'Research and Development'}),
(c19:Company {name: 'Government'}),
(c20:Company {name: 'Intelligence'}),
(c21:Company {name: 'Military'}),

// Source: Suresh and Guttag. A Framework for Understanding Sources of Harm␣
↪throughout the Machine Learning Lifecycle. 2021.

(a0:ML_Workflow {name: 'World', bias: 'Historical Bias'}), //
(a00:PROCESS {name: 'Data Generation'}),
(a01:PROCESS {name: 'Population Definition & Sampling'}),
(a000:BIAS {name: 'Historical Bias'}),
(a1:ML_Workflow {name: 'Sample'}), //
(a10:PROCESS {name: 'Measurement'}),
(a100:BIAS {name: 'Representation Bias'}),
(a2:ML_Workflow {name: 'Dataset'}), //
(a20:PROCESS {name: 'Preprocessing, Train/Test Split'}),
(a200:BIAS {name: 'Measurement Bias'}),
(a3:ML_Workflow {name: 'Training Data'}), //
(a30:PROCESS {name: 'Model Learning'}),
(a300:BIAS {name: 'Learning Bias'}),
(a4:ML_Workflow {name: 'Test Data'}), //
(a40:PROCESS {name: 'Evaluation'}),
(a400:BIAS {name: 'Evaluation Bias'}),
(a5:ML_Workflow {name: 'Benchmarks'}), // feeds evaluation
(a60:PROCESS {name: 'Model Definition'}), //  feeds model
(a600:BIAS {name: 'Aggregation Bias'}),
(a7:ML_Workflow {name: 'Model'}), // feeds model output
(a70:PROCESS {name: 'Run Model'}),
(a8:ML_Workflow {name: 'Model Output'}), //
(a80:PROCESS {name: 'Post-Process'}),
(a81:PROCESS {name: 'Integrate into Systems'}),
(a82:PROCESS {name: 'Human & Model Interaction'}),
(a800:BIAS {name: 'Deployment Bias'}),

(c0)-[:FEEDS {since: 1984}]->(c00),
(c00)-[:FEEDS]->(c1),
(c1)-[:FEEDS]->(c2),
 (c1)-[:FEEDS]->(c3),
 (c1)-[:FEEDS]->(c4),
 (c1)-[:FEEDS]->(c5),
 (c1)-[:FEEDS]->(c6),
 (c1)-[:FEEDS]->(c7),
 (c1)-[:FEEDS]->(c8),
 (c1)-[:FEEDS]->(c9),
 (c1)-[:FEEDS]->(c10),
 (c1)-[:FEEDS]->(c11),
 (c1)-[:FEEDS]->(c12),
 (c1)-[:FEEDS]->(c13),
 (c1)-[:FEEDS]->(c14),
 (c1)-[:FEEDS]->(c15),
 (c1)-[:FEEDS]->(c16),
 (c1)-[:FEEDS]->(c17),
 (c1)-[:FEEDS]->(c18),
 (c1)-[:FEEDS]->(c19),
 (c1)-[:FEEDS]->(c20),
 (c1)-[:FEEDS]->(c21),

 // Source: Suresh and Guttag. A Framework for Understanding Sources of Harm␣
↪throughout the Machine Learning Lifecycle. 2021.
 (a0)-[:FEEDS]->(a00), //
 (a0)-[:FEEDS]->(a01), //
 (a00)-[:FEEDS]->(a0),
 (a01)-[:FEEDS]->(a1),
 (a000)-[:BIASES]->(a0),
 (a000)-[:BIASES]->(a00),
 (a1)-[:FEEDS]->(a10), //
 (a10)-[:FEEDS]->(a2),
 (a100)-[:BIASES]->(a01),
 (a100)-[:BIASES]->(a1),
 (a2)-[:FEEDS]->(a20), //
 (a20)-[:FEEDS]->(a3),
 (a20)-[:FEEDS]->(a4),
 (a200)-[:BIASES]->(a10),
 (a200)-[:BIASES]->(a2),
 (a200)-[:BIASES]->(a20),
 (a30)-[:FEEDS]->(a7), //
 (a7)-[:FEEDS]->(a30),
 (a3)-[:FEEDS]->(a30),
 (a300)-[:BIASES]->(a3),
 (a300)-[:BIASES]->(a30),
 (a300)-[:BIASES]->(a7),
 (a4)-[:FEEDS]->(a40), //
 (a40)-[:FEEDS]->(a7),
 (a400)-[:BIASES]->(a4),
(a400)-[:BIASES]->(a40),
(a400)-[:BIASES]->(a5),
(a400)-[:BIASES]->(a7),
(a5)-[:FEEDS]->(a40), //
(a60)-[:FEEDS]->(a7), //
(a600)-[:BIASES]->(a60),
(a600)-[:BIASES]->(a7),
(a7)-[:FEEDS]->(a70), //
(a70)-[:FEEDS]->(a8),
(a8)-[:FEEDS]->(a80), //
(a8)-[:FEEDS]->(a81),
(a8)-[:FEEDS]->(a82),
(a80)-[:FEEDS]->(a0),
(a81)-[:FEEDS]->(a0),
(a82)-[:FEEDS]->(a0),
(a800)-[:BIASES]->(a8),
(a800)-[:BIASES]->(a70),
(a800)-[:BIASES]->(a80),
(a800)-[:BIASES]->(a81),
(a800)-[:BIASES]->(a82),
(a800)-[:BIASES]->(a0),

//
(c00)-[:FEEDS]->(a70),
// New relationships between c1-c21 and a0: World
(c1)-[:FEEDS]->(a0),
(c2)-[:FEEDS]->(a0),
(c3)-[:FEEDS]->(a0),
(c4)-[:FEEDS]->(a0),
(c5)-[:FEEDS]->(a0),
(c6)-[:FEEDS]->(a0),
(c7)-[:FEEDS]->(a0),
(c8)-[:FEEDS]->(a0),
(c9)-[:FEEDS]->(a0),
(c10)-[:FEEDS]->(a0),
(c11)-[:FEEDS]->(a0),
(c12)-[:FEEDS]->(a0),
(c13)-[:FEEDS]->(a0),
(c14)-[:FEEDS]->(a0),
(c15)-[:FEEDS]->(a0),
(c16)-[:FEEDS]->(a0),
(c17)-[:FEEDS]->(a0),
(c18)-[:FEEDS]->(a0),
(c19)-[:FEEDS]->(a0),
(c20)-[:FEEDS]->(a0),
(c21)-[:FEEDS]->(a0),
  // link population definition and sampling, measurement, preprocessing tran/
↪test split, and benchmarks
  (a01)-[:FEEDS]->(a10),
  (a10)-[:FEEDS]->(a20),
  (a20)-[:FEEDS]->(a5), //done with Set A enhancements

  // Linking Sets A and C
  (a7)-[:FEEDS]->(c00), // Model feeds OpenAI Global
  (c00)-[:FEEDS]->(a8), // OpenAI Global runs the model

  //one last thing
  (a800)-[:BIASES]->(c00) // Deployment Bias affects OpenAI Global

"""

session.run(query)
```

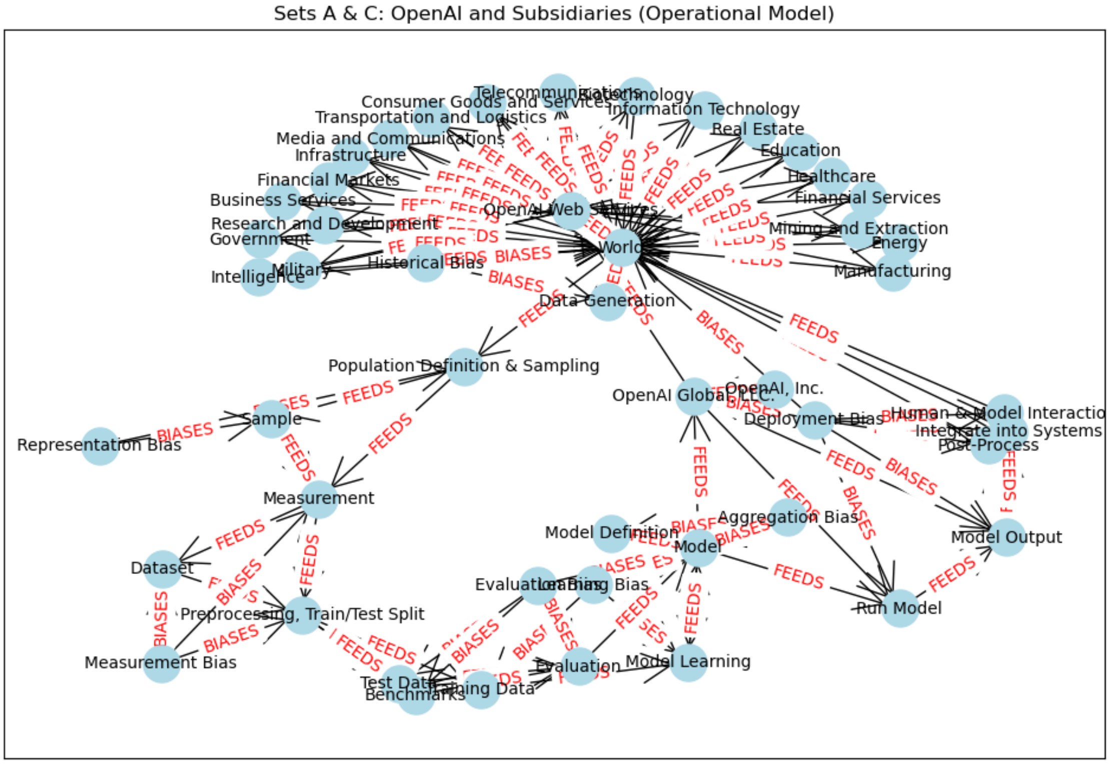
[63]:
```
<neo4j._sync.work.result.Result at 0x176fd5120>
```

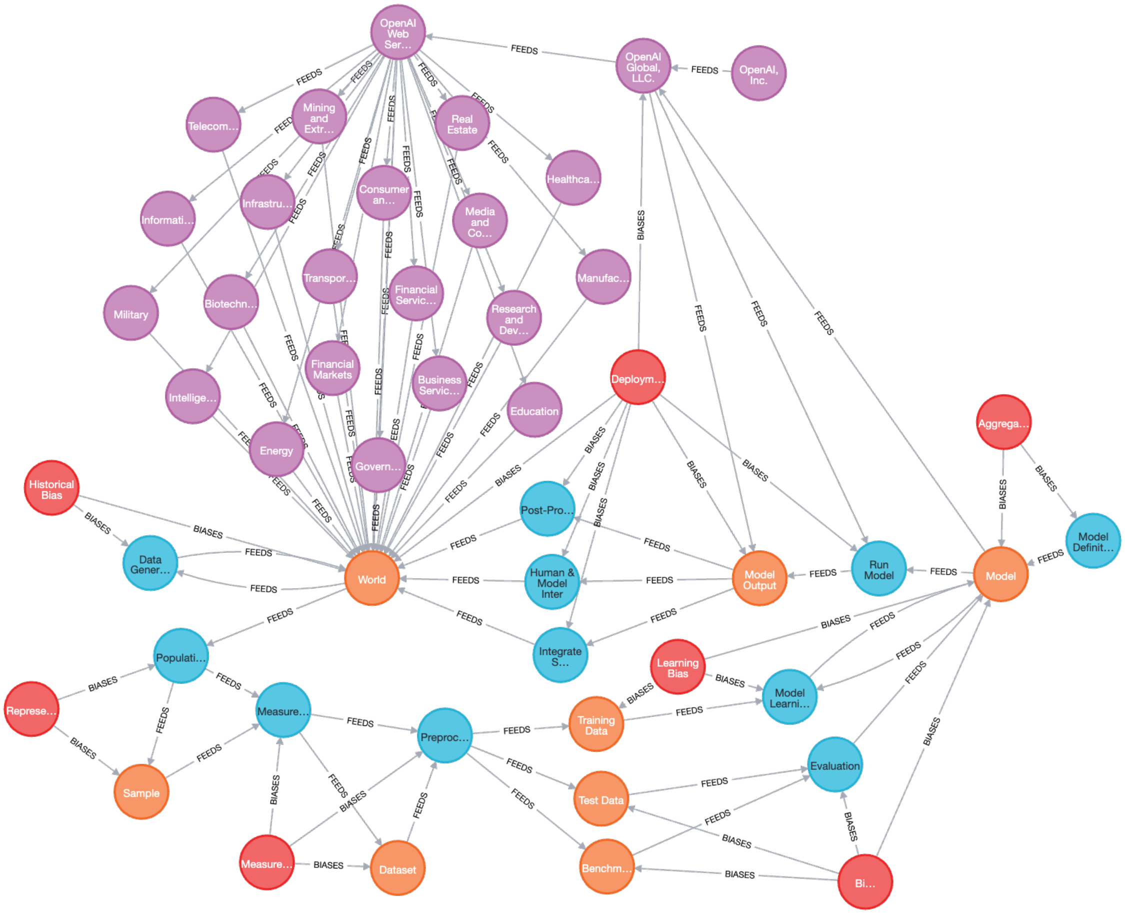
[64]:
```
my_neo4j_nodes_relationships()
visualize_graph('Sets A & C: OpenAI and Subsidiaries (Operational Model)')
```

```
-------------------------
  Nodes:
-------------------------

                           node_name         labels
0                   Aggregation Bias         [BIAS]
1                         Benchmarks  [ML_Workflow]
2                      Biotechnology      [Company]
3                  Business Services      [Company]
4        Consumer Goods and Services      [Company]
5                    Data Generation      [PROCESS]
6                            Dataset  [ML_Workflow]
7                    Deployment Bias         [BIAS]
8                          Education      [Company]
9                             Energy      [Company]
10                        Evaluation      [PROCESS]
11                   Evaluation Bias         [BIAS]
12                 Financial Markets      [Company]
13                Financial Services      [Company]
14                        Government      [Company]
15                        Healthcare      [Company]
16                   Historical Bias         [BIAS]
17         Human & Model Interaction      [PROCESS]
18            Information Technology      [Company]
19                    Infrastructure      [Company]
20            Integrate into Systems      [PROCESS]
```

```
21                      Intelligence      [Company]
22                     Learning Bias         [BIAS]
23                     Manufacturing      [Company]
24                       Measurement      [PROCESS]
25                  Measurement Bias         [BIAS]
26          Media and Communications      [Company]
27                          Military      [Company]
28             Mining and Extraction      [Company]
29                             Model  [ML_Workflow]
30                  Model Definition      [PROCESS]
31                    Model Learning      [PROCESS]
32                      Model Output  [ML_Workflow]
33               OpenAI Global, LLC.      [Company]
34               OpenAI Web Services      [Company]
35                      OpenAI, Inc.      [Company]
36  Population Definition & Sampling      [PROCESS]
37                      Post-Process      [PROCESS]
38   Preprocessing, Train/Test Split      [PROCESS]
39                       Real Estate      [Company]
40               Representation Bias         [BIAS]
41          Research and Development      [Company]
42                         Run Model      [PROCESS]
43                            Sample  [ML_Workflow]
44                Telecommunications      [Company]
45                         Test Data  [ML_Workflow]
46                     Training Data  [ML_Workflow]
47      Transportation and Logistics      [Company]
48                             World  [ML_Workflow]

-------------------------
  Relationships:
-------------------------

                     node_name_1  node_1_labels relationship_type  \
0               Aggregation Bias         [BIAS]            BIASES
1               Aggregation Bias         [BIAS]            BIASES
2                     Benchmarks  [ML_Workflow]             FEEDS
3                  Biotechnology      [Company]             FEEDS
4              Business Services      [Company]             FEEDS
..                           …            …               …
91                     Test Data  [ML_Workflow]             FEEDS
92                 Training Data  [ML_Workflow]             FEEDS
93  Transportation and Logistics      [Company]             FEEDS
94                         World  [ML_Workflow]             FEEDS
95                         World  [ML_Workflow]             FEEDS

                         node_name_2  node_2_labels
0                              Model  [ML_Workflow]
1                   Model Definition      [PROCESS]
```

```
2                         Evaluation      [PROCESS]
3                              World  [ML_Workflow]
4                              World  [ML_Workflow]
..                               ...            ...
91                        Evaluation      [PROCESS]
92                    Model Learning      [PROCESS]
93                             World  [ML_Workflow]
94                   Data Generation      [PROCESS]
95  Population Definition & Sampling      [PROCESS]

[96 rows x 5 columns]

-------------------------
  Density: 0.1
-------------------------
```


Sets A & C: OpenAI and Subsidiaries (Operational Model)



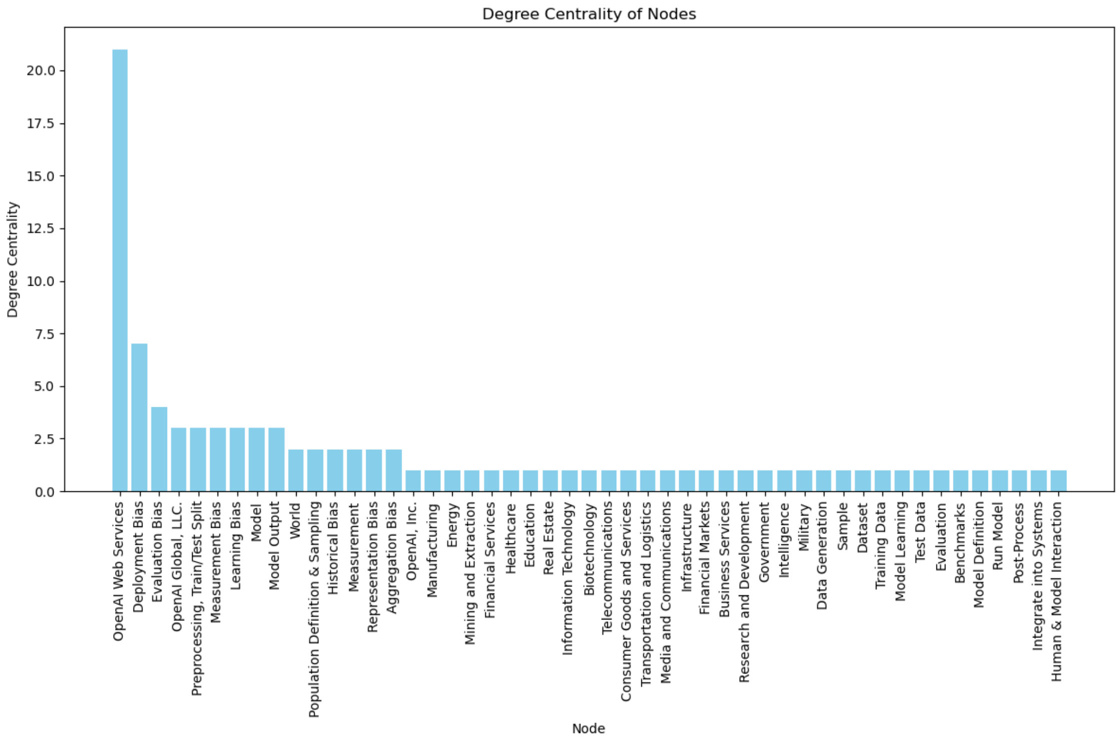
3.5 Algorithm 1: Degree Centrality

```
[53]: def my_neo4j_degree_centrality():
          """
          Compute the degree centrality for all nodes in the graph, print the␣
       ↪results, and plot them.
          """
          driver = GraphDatabase.driver(uri="neo4j://54.156.52.158:7687",␣
       ↪auth=("neo4j", "ucb_mids_w205"))
          session = driver.session(database="neo4j")

          # Drop the graph if it already exists
          query = "CALL gds.graph.drop('ds_graph', false)"
          session.run(query)

          # Project the graph
          query = """
          CALL gds.graph.project(
              'ds_graph',
              ['Company', 'ML_Workflow', 'PROCESS', 'BIAS'],
              ['IS_PARENT_OF', 'FEEDS', 'BIASES']
```

```
    )
    """
    session.run(query)

    # Run the degree centrality algorithm
    query = """
    CALL gds.degree.stream('ds_graph')
    YIELD nodeId, score AS centrality
    RETURN gds.util.asNode(nodeId).name AS node, centrality
    ORDER BY centrality DESC
    """

    result = session.run(query)

    data = []
    for r in result:
        data.append({"Node": r['node'], "Degree Centrality": r['centrality']})
    df = pd.DataFrame(data)

    print("\n--------------------------------")
    print("   Degree Centrality Results")
    print("--------------------------------")
    print(df)
    plt.figure(figsize=(12, 8))
    plt.bar(df['Node'], df['Degree Centrality'], color='skyblue')
    plt.xlabel('Node')
    plt.ylabel('Degree Centrality')
    plt.title('Degree Centrality of Nodes')
    plt.xticks(rotation=90)
    plt.tight_layout()
    plt.show()

my_neo4j_degree_centrality()
```

```
Received notification from DBMS server: {severity: WARNING} {code:
Neo.ClientNotification.Statement.FeatureDeprecationWarning} {category:
DEPRECATION} {title: This feature is deprecated and will be removed in future
versions.} {description: The query used a deprecated field from a procedure.
('schema' returned by 'gds.graph.drop' is deprecated.)} {position: line: 1,
column: 1, offset: 0} for query: "CALL gds.graph.drop('ds_graph', false)"


--------------------------------
   Degree Centrality Results
--------------------------------
                                Node  Degree Centrality
0                OpenAI Web Services               21.0
1                    Deployment Bias                7.0
```

```
2                     Evaluation Bias                4.0
3                 OpenAI Global, LLC.                3.0
4     Preprocessing, Train/Test Split                3.0
5                    Measurement Bias                3.0
6                       Learning Bias                3.0
7                               Model                3.0
8                        Model Output                3.0
9                               World                2.0
10  Population Definition & Sampling                2.0
11                    Historical Bias                2.0
12                        Measurement                2.0
13                Representation Bias                2.0
14                   Aggregation Bias                2.0
15                       OpenAI, Inc.                1.0
16                      Manufacturing                1.0
17                             Energy                1.0
18              Mining and Extraction                1.0
19                 Financial Services                1.0
20                         Healthcare                1.0
21                          Education                1.0
22                        Real Estate                1.0
23             Information Technology                1.0
24                      Biotechnology                1.0
25                 Telecommunications                1.0
26        Consumer Goods and Services                1.0
27       Transportation and Logistics                1.0
28           Media and Communications                1.0
29                     Infrastructure                1.0
30                  Financial Markets                1.0
31                  Business Services                1.0
32           Research and Development                1.0
33                         Government                1.0
34                       Intelligence                1.0
35                           Military                1.0
36                    Data Generation                1.0
37                             Sample                1.0
38                            Dataset                1.0
39                      Training Data                1.0
40                     Model Learning                1.0
41                          Test Data                1.0
42                         Evaluation                1.0
43                         Benchmarks                1.0
44                   Model Definition                1.0
45                          Run Model                1.0
46                       Post-Process                1.0
47             Integrate into Systems                1.0
48           Human & Model Interaction                1.0
```



Degree Centrality measures the number of direct connections a graph node has and is a proxy for how important or influential a node might be in the network.

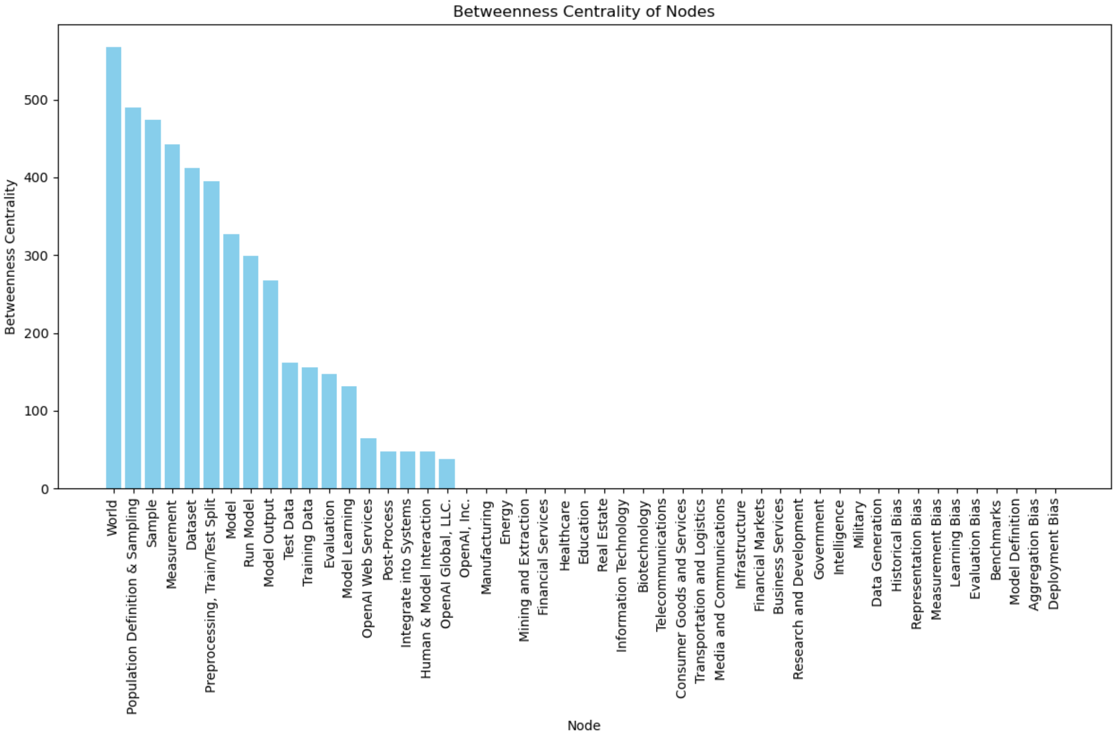
- OpenAI Web Services (OWS) has the highest number of direct connections, by far
- Deployment and Evaluation Biases are next
- The non-profit parent company, Open AI, Inc., who is technically the owner and operator of OpenAI Global, LLC, has a less central role in how influential it is throughout the graph.

3.6 Algorithm 2: Betweenness Centrality

[20]:
```
def my_neo4j_betweenness_centrality():
    """
    Compute the betweenness centrality for all nodes in the graph, print the␣
 ↪results, and plot them.
    """
    driver = GraphDatabase.driver(uri="neo4j://54.156.52.158:7687",␣
 ↪auth=("neo4j", "ucb_mids_w205"))
    session = driver.session(database="neo4j")

    # Drop the graph if it already exists
    query = "CALL gds.graph.drop('ds_graph', false)"
    session.run(query)

    # Project the graph
    query = """
    CALL gds.graph.project(
        'ds_graph',
        ['Company', 'ML_Workflow', 'PROCESS', 'BIAS'],
        ['IS_PARENT_OF', 'FEEDS', 'BIASES']
    )
    """
    session.run(query)

    # Run the betweenness centrality algorithm
    query = """
    CALL gds.betweenness.stream('ds_graph')
    YIELD nodeId, score
    RETURN gds.util.asNode(nodeId).name AS node, score AS betweenness
    ORDER BY betweenness DESC
    """

    result = session.run(query)

    # Store the results in a df
    data = []
    for r in result:
        data.append({"Node": r['node'], "Betweenness Centrality":␣
  ↪r['betweenness']})

    df = pd.DataFrame(data)

    print("\n---------------------------------")
    print("   Betweenness Centrality Results")
    print("---------------------------------")
    print(df)

    plt.figure(figsize=(12, 8))
    plt.bar(df['Node'], df['Betweenness Centrality'], color='skyblue')
    plt.xlabel('Node')
    plt.ylabel('Betweenness Centrality')
    plt.title('Betweenness Centrality of Nodes')
    plt.xticks(rotation=90)
    plt.tight_layout()
    plt.show()

my_neo4j_betweenness_centrality()
```

```
Received notification from DBMS server: {severity: WARNING} {code:
Neo.ClientNotification.Statement.FeatureDeprecationWarning} {category:
DEPRECATION} {title: This feature is deprecated and will be removed in future
versions.} {description: The query used a deprecated field from a procedure.
('schema' returned by 'gds.graph.drop' is deprecated.)} {position: line: 1,
column: 1, offset: 0} for query: "CALL gds.graph.drop('ds_graph', false)"


--------------------------------
   Betweenness Centrality Results
--------------------------------
                                Node  Betweenness Centrality
0                              World              568.000000
1   Population Definition & Sampling              490.000000
2                             Sample              474.000000
3                        Measurement              443.000000
4                            Dataset              412.000000
5    Preprocessing, Train/Test Split              395.000000
6                              Model              327.000000
7                          Run Model              299.000000
8                       Model Output              268.000000
9                          Test Data              161.500000
10                     Training Data              155.500000
11                        Evaluation              147.500000
12                    Model Learning              131.500000
13               OpenAI Web Services               64.000000
14                      Post-Process               47.666667
15            Integrate into Systems               47.666667
16         Human & Model Interaction               47.666667
17               OpenAI Global, LLC.               38.000000
18                      OpenAI, Inc.                0.000000
19                     Manufacturing                0.000000
20                            Energy                0.000000
21             Mining and Extraction                0.000000
22                Financial Services                0.000000
23                        Healthcare                0.000000
24                         Education                0.000000
25                       Real Estate                0.000000
26            Information Technology                0.000000
27                     Biotechnology                0.000000
28                Telecommunications                0.000000
29       Consumer Goods and Services                0.000000
30      Transportation and Logistics                0.000000
31          Media and Communications                0.000000
32                    Infrastructure                0.000000
33                 Financial Markets                0.000000
34                 Business Services                0.000000
35          Research and Development                0.000000
36                        Government                0.000000
37                      Intelligence                0.000000
38                          Military                0.000000
39                   Data Generation                0.000000
40                   Historical Bias                0.000000
```

```
41                Representation Bias              0.000000
42                   Measurement Bias              0.000000
43                      Learning Bias              0.000000
44                    Evaluation Bias              0.000000
45                         Benchmarks              0.000000
46                   Model Definition              0.000000
47                   Aggregation Bias              0.000000
48                    Deployment Bias              0.000000
```



Betweenness Centrality measures the number of times a node acts as a bridge along the shortest path between two other nodes. It serves as a proxy for how important a node is in controlling the flow of information or energy within the graph network

- The World, Population & Sampling, Measuring and making Datasets are all the most important aspects of bridging the shortest paths between other nodes. The results indicate that in a high flow rate environment, globally, operational changes within these aspects of the graph could have outsized positive (or negative) influence, accumulating changes across each traversal.

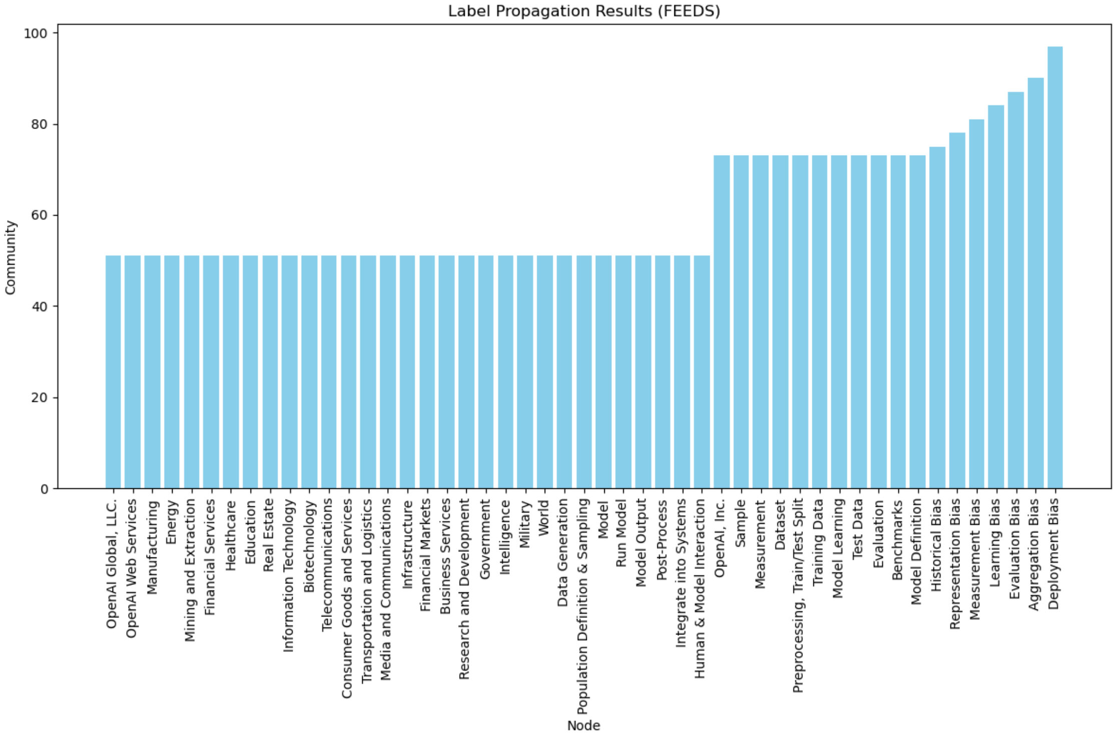
3.7 Algorithm 3: Label Propagation

```
[91]: def my_neo4j_lpa_pull(max_iterations=10):
          driver = GraphDatabase.driver(uri="neo4j://54.156.52.158:7687",␣
       ↪auth=("neo4j", "ucb_mids_w205"))
```

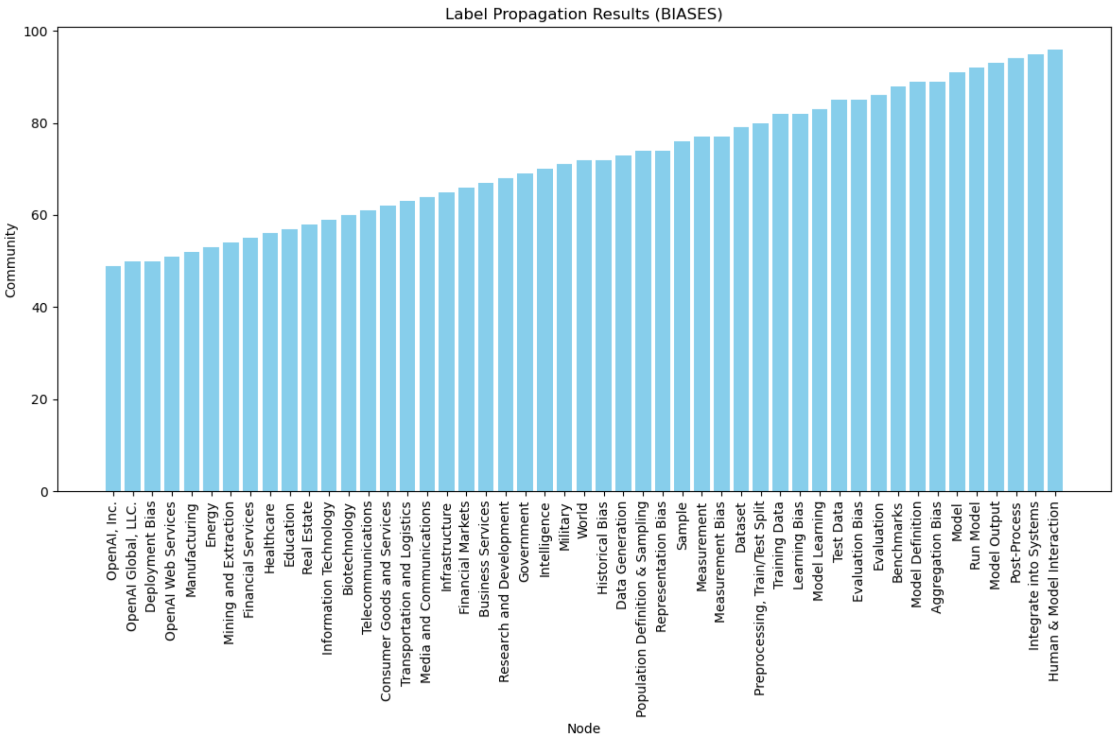
```
session = driver.session(database="neo4j")

relationships = ['FEEDS', 'BIASES']
for i, relationship in enumerate(relationships):
    graph_name = f'ds_graph_{relationship.lower()}'

    query = f"CALL gds.graph.drop('{graph_name}', false)"
    session.run(query)

    # Preprocess relationships to add weight property based on their count
    if relationship == 'FEEDS':
        preprocess_query = """
        MATCH (a)-[r:FEEDS]->(b)
        WITH a, b, COUNT(r) AS weight
        MERGE (a)-[newR:FEEDS {weight: weight}]->(b)
        """
    elif relationship == 'BIASES':
        preprocess_query = """
        MATCH (a)-[r:BIASES]->(b)
        WITH a, b, COUNT(r) AS weight
        MERGE (a)-[newR:BIASES {weight: weight}]->(b)
        """
    session.run(preprocess_query)

    query = f"""
    CALL gds.graph.project(
        '{graph_name}',
        ['Company', 'ML_Workflow', 'PROCESS', 'BIAS'],
        {{
            {relationship}: {{
                orientation: 'NATURAL',
                properties: {{
                    weight: {{
                        defaultValue: 1.0
                    }}
                }}
            }}
        }}
    )
    """
    session.run(query)

    query = f"""
    CALL gds.labelPropagation.stream('{graph_name}', {{
        maxIterations: {max_iterations},
        relationshipWeightProperty: 'weight'
    }})
```

```
        YIELD nodeId, communityId
        RETURN gds.util.asNode(nodeId).name AS node, communityId
        ORDER BY communityId
        """
        result = session.run(query)

        data = []
        for r in result:
            data.append({"Node": r['node'], "Community": r['communityId']})
        df = pd.DataFrame(data)
        print(f"\n--------------------------------")
        print(f" Label Propagation Results ({relationship})")
        print("--------------------------------")
        print(df)

        # Plot the results
        plt.figure(figsize=(12, 8))
        plt.bar(df['Node'], df['Community'], color='skyblue')
        plt.xlabel('Node')
        plt.ylabel('Community')
        plt.title(f'Label Propagation Results ({relationship})')
        plt.xticks(rotation=90)
        plt.tight_layout()
        plt.show()

my_neo4j_lpa_pull(max_iterations=10)
```

```
Received notification from DBMS server: {severity: WARNING} {code:
Neo.ClientNotification.Statement.FeatureDeprecationWarning} {category:
DEPRECATION} {title: This feature is deprecated and will be removed in future
versions.} {description: The query used a deprecated field from a procedure.
('schema' returned by 'gds.graph.drop' is deprecated.)} {position: line: 1,
column: 1, offset: 0} for query: "CALL gds.graph.drop('ds_graph_feeds', false)"


--------------------------------
 Label Propagation Results (FEEDS)
--------------------------------
                                Node  Community
0                OpenAI Global, LLC.         51
1                OpenAI Web Services         51
2                      Manufacturing         51
3                             Energy         51
4              Mining and Extraction         51
5                 Financial Services         51
6                         Healthcare         51
7                          Education         51
8                        Real Estate         51
```



```
Received notification from DBMS server: {severity: WARNING} {code:
Neo.ClientNotification.Statement.FeatureDeprecationWarning} {category:
DEPRECATION} {title: This feature is deprecated and will be removed in future
versions.} {description: The query used a deprecated field from a procedure.
('schema' returned by 'gds.graph.drop' is deprecated.)} {position: line: 1,
column: 1, offset: 0} for query: "CALL gds.graph.drop('ds_graph_biases', false)"


--------------------------------
 Label Propagation Results (BIASES)
--------------------------------
                                Node  Community
0                       OpenAI, Inc.         49
1                OpenAI Global, LLC.         50
2                    Deployment Bias         50
3                OpenAI Web Services         51
4                      Manufacturing         52
5                             Energy         53
6              Mining and Extraction         54
7                 Financial Services         55
8                         Healthcare         56
9                          Education         57
10                       Real Estate         58
11            Information Technology         59
```



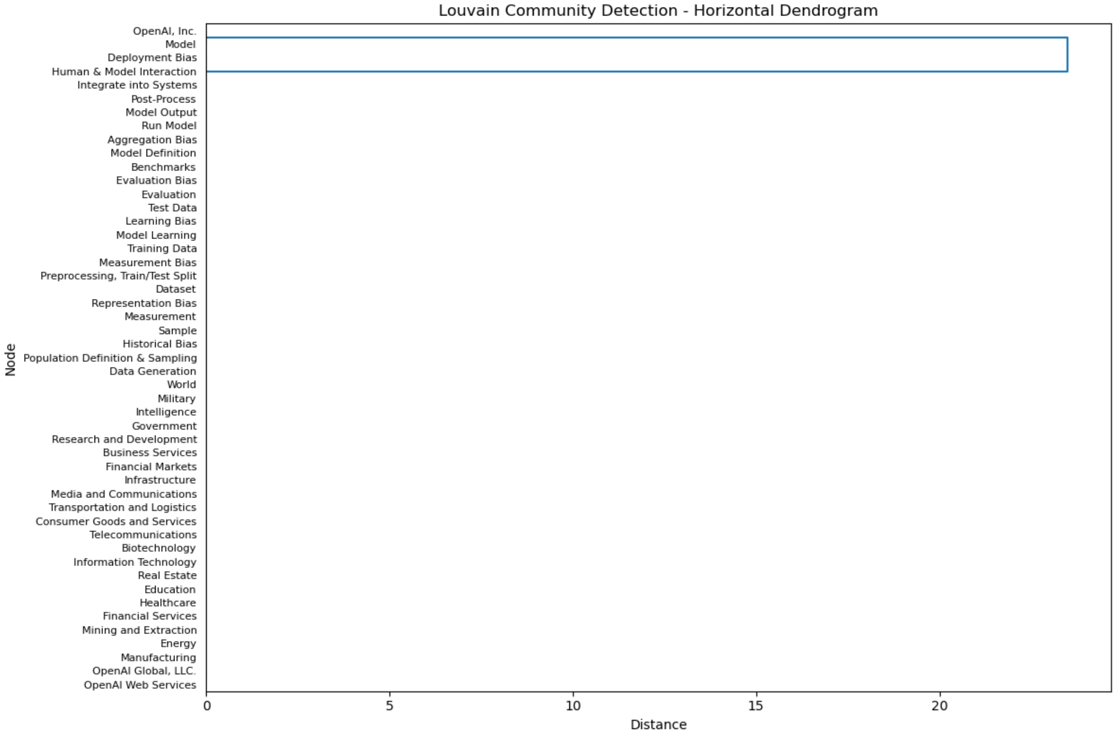
3.8 Ungraded Additional Algorithms for Exploration

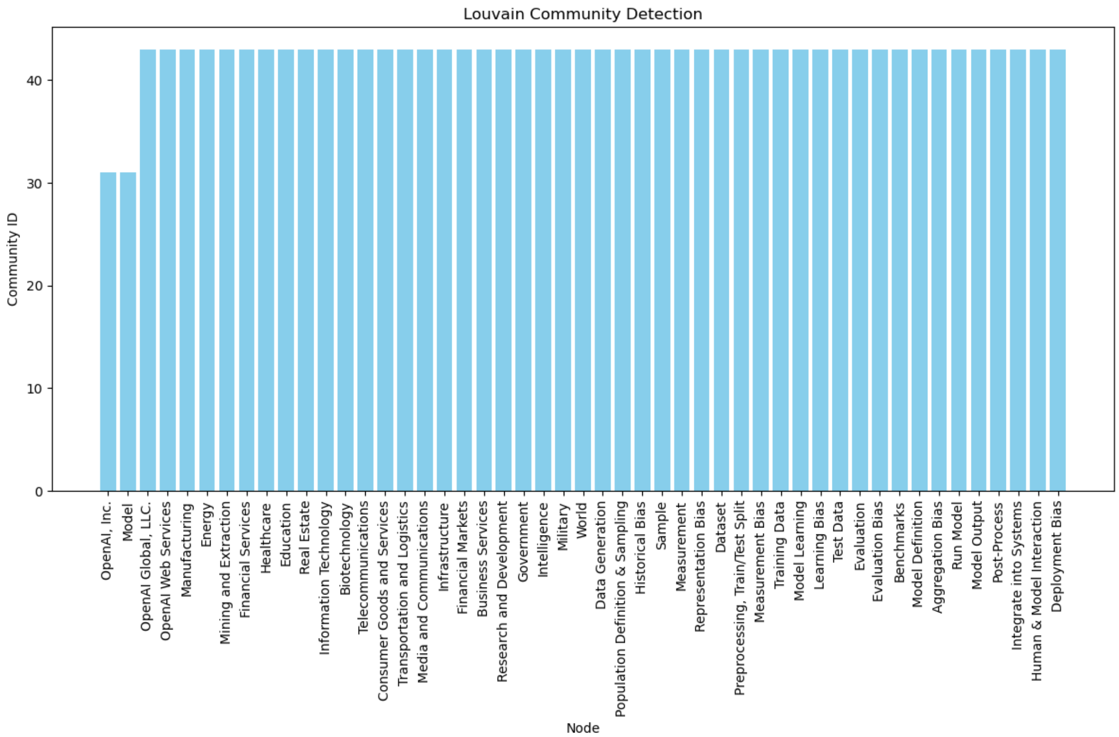
3.8.1 Algorithm 4: Louvain Modularity

[94]:
```
def my_neo4j_louvain_modularity():
    """
    Compute the Louvain modularity for all nodes in the graph, print the␣
 ↪results, and plot them.
    """
    driver = GraphDatabase.driver(uri="neo4j://54.156.52.158:7687",␣
 ↪auth=("neo4j", "ucb_mids_w205"))
    session = driver.session(database="neo4j")

    # Drop the graph if it already exists
    query = "CALL gds.graph.drop('ds_graph', false)"
    session.run(query)

    # Project the graph
    query = """
    CALL gds.graph.project(
        'ds_graph',
        ['Company', 'ML_Workflow', 'PROCESS', 'BIAS'],
        ['IS_PARENT_OF', 'FEEDS', 'BIASES']
    )
    """
    session.run(query)

    # Run the Louvain modularity algorithm
    query = """
    CALL gds.louvain.stream('ds_graph')
    YIELD nodeId, communityId
    RETURN gds.util.asNode(nodeId).name AS node, communityId
    ORDER BY communityId
    """

    result = session.run(query)

    # Store the results in a DataFrame
    data = []
    for r in result:
        data.append({"Node": r['node'], "Community ID": r['communityId']})

    df = pd.DataFrame(data)

    # Print the results
    print("\n--------------------------------")
    print("   Louvain Modularity Results")
    print("--------------------------------")
    print(df)


    # horizontal dendrogram
    plt.figure(figsize=(12, 8))
    linked = linkage(df['Community ID'].values.reshape(-1, 1), method='ward')
    dendrogram(linked, labels=df['Node'].values, orientation='right',␣
 ↪distance_sort='descending', show_leaf_counts=True)

    plt.xlabel('Distance')
    plt.ylabel('Node')
    plt.title('Louvain Community Detection - Horizontal Dendrogram')
    plt.tight_layout()
    plt.show()

    # bar plot
    plt.figure(figsize=(12, 8))
    plt.bar(df['Node'], df['Community ID'], color='skyblue')
    plt.xlabel('Node')
    plt.ylabel('Community ID')
    plt.title('Louvain Community Detection')
    plt.xticks(rotation=90)
    plt.tight_layout()
    plt.show()

my_neo4j_louvain_modularity()
```

```
Received notification from DBMS server: {severity: WARNING} {code:
Neo.ClientNotification.Statement.FeatureDeprecationWarning} {category:
DEPRECATION} {title: This feature is deprecated and will be removed in future
versions.} {description: The query used a deprecated field from a procedure.
('schema' returned by 'gds.graph.drop' is deprecated.)} {position: line: 1,
column: 1, offset: 0} for query: "CALL gds.graph.drop('ds_graph', false)"


--------------------------------
   Louvain Modularity Results
--------------------------------
                                Node  Community ID
0                       OpenAI, Inc.            31
1                              Model            31
2                OpenAI Global, LLC.            43
3                OpenAI Web Services            43
4                      Manufacturing            43
5                             Energy            43
6              Mining and Extraction            43
7                 Financial Services            43
8                         Healthcare            43
9                          Education            43
10                       Real Estate            43
11            Information Technology            43
12                     Biotechnology            43
13                Telecommunications            43
14       Consumer Goods and Services            43
15      Transportation and Logistics            43
16          Media and Communications            43
17                    Infrastructure            43
18                 Financial Markets            43
19                 Business Services            43
20          Research and Development            43
21                        Government            43
22                      Intelligence            43
23                          Military            43
24                             World            43
25                   Data Generation            43
26  Population Definition & Sampling            43
27                   Historical Bias            43
28                            Sample            43
29                       Measurement            43
30               Representation Bias            43
```

31	Dataset	43
32	Preprocessing, Train/Test Split	43
33	Measurement Bias	43
34	Training Data	43
35	Model Learning	43
36	Learning Bias	43
37	Test Data	43
38	Evaluation	43
39	Evaluation Bias	43
40	Benchmarks	43
41	Model Definition	43
42	Aggregation Bias	43
43	Run Model	43
44	Model Output	43
45	Post-Process	43
46	Integrate into Systems	43
47	Human & Model Interaction	43
48	Deployment Bias	43





3.8.2 Algorithm 5: Harmonic Centrality

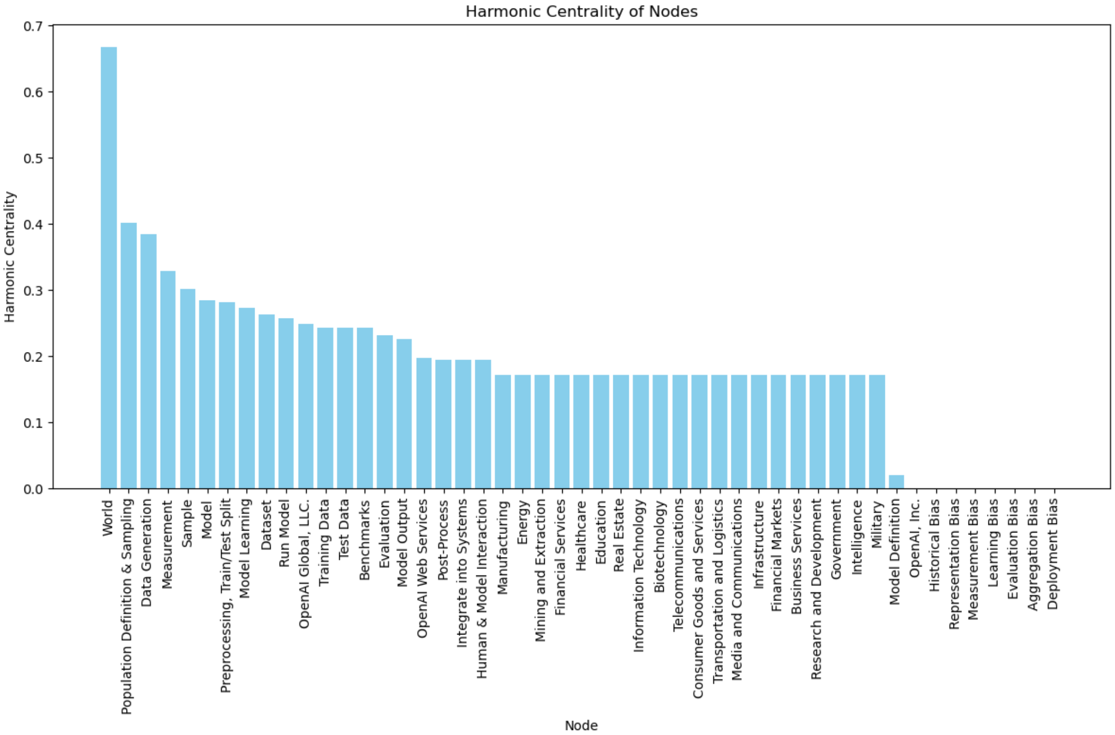
```
[93]: def my_neo4j_harmonic_centrality():
          """
          Compute the harmonic centrality for all nodes in the graph, print the␣
        ↪results, and plot them.
          """
          driver = GraphDatabase.driver(uri="neo4j://54.156.52.158:7687",␣
        ↪auth=("neo4j", "ucb_mids_w205"))
          session = driver.session(database="neo4j")

          # Drop the graph if it already exists
          query = "CALL gds.graph.drop('ds_graph', false)"
          session.run(query)

          # Project the graph
          query = """
          CALL gds.graph.project(
              'ds_graph',
              ['Company', 'ML_Workflow', 'PROCESS', 'BIAS'],
              ['IS_PARENT_OF', 'FEEDS', 'BIASES']
          )
          """
```

```python
    session.run(query)

    # Run the harmonic centrality algorithm
    query = """
    CALL gds.alpha.closeness.harmonic.stream('ds_graph')
    YIELD nodeId, centrality
    RETURN gds.util.asNode(nodeId).name AS node, centrality
    ORDER BY centrality DESC
    """

    result = session.run(query)
    data = []
    for r in result:
        data.append({"Node": r['node'], "Harmonic Centrality": r['centrality']})

    df = pd.DataFrame(data)

    print("\n--------------------------------")
    print("   Harmonic Centrality Results")
    print("--------------------------------")
    print(df)

    plt.figure(figsize=(12, 8))
    plt.bar(df['Node'], df['Harmonic Centrality'], color='skyblue')
    plt.xlabel('Node')
    plt.ylabel('Harmonic Centrality')
    plt.title('Harmonic Centrality of Nodes')
    plt.xticks(rotation=90)
    plt.tight_layout()
    plt.show()

my_neo4j_harmonic_centrality()
```

```
Received notification from DBMS server: {severity: WARNING} {code:
Neo.ClientNotification.Statement.FeatureDeprecationWarning} {category:
DEPRECATION} {title: This feature is deprecated and will be removed in future
versions.} {description: The query used a deprecated field from a procedure.
('schema' returned by 'gds.graph.drop' is deprecated.)} {position: line: 1,
column: 1, offset: 0} for query: "CALL gds.graph.drop('ds_graph', false)"
Received notification from DBMS server: {severity: WARNING} {code:
Neo.ClientNotification.Statement.FeatureDeprecationWarning} {category:
DEPRECATION} {title: This feature is deprecated and will be removed in future
versions.} {description: The query used a deprecated procedure.
('gds.alpha.closeness.harmonic.stream' has been replaced by
'gds.closeness.harmonic.stream')} {position: line: 2, column: 1, offset: 5} for
query: "\n    CALL gds.alpha.closeness.harmonic.stream('ds_graph')\n    YIELD
nodeId, centrality\n    RETURN gds.util.asNode(nodeId).name AS node,
centrality\n    ORDER BY centrality DESC\n    "
```

```
--------------------------------
   Harmonic Centrality Results
--------------------------------
                                Node  Harmonic Centrality
0                              World             0.667841
1   Population Definition & Sampling             0.400951
2                    Data Generation             0.384516
3                        Measurement             0.328431
4                             Sample             0.301811
5                              Model             0.284292
6    Preprocessing, Train/Test Split             0.282267
7                     Model Learning             0.272966
8                            Dataset             0.263748
9                          Run Model             0.256878
10               OpenAI Global, LLC.             0.248545
11                     Training Data             0.243246
12                         Test Data             0.243246
13                        Benchmarks             0.243246
14                        Evaluation             0.231357
15                      Model Output             0.226554
16               OpenAI Web Services             0.196967
17                      Post-Process             0.194461
18            Integrate into Systems             0.194461
19         Human & Model Interaction             0.194461
20                     Manufacturing             0.171702
21                            Energy             0.171702
22             Mining and Extraction             0.171702
23                Financial Services             0.171702
24                        Healthcare             0.171702
25                         Education             0.171702
26                       Real Estate             0.171702
27            Information Technology             0.171702
28                     Biotechnology             0.171702
29                Telecommunications             0.171702
30       Consumer Goods and Services             0.171702
31      Transportation and Logistics             0.171702
32          Media and Communications             0.171702
33                    Infrastructure             0.171702
34                 Financial Markets             0.171702
35                 Business Services             0.171702
36          Research and Development             0.171702
37                        Government             0.171702
38                      Intelligence             0.171702
39                          Military             0.171702
40                  Model Definition             0.020833
41                      OpenAI, Inc.             0.000000
42                   Historical Bias             0.000000
```

```
43                Representation Bias            0.000000
44                   Measurement Bias            0.000000
45                      Learning Bias            0.000000
46                    Evaluation Bias            0.000000
47                   Aggregation Bias            0.000000
48                    Deployment Bias            0.000000
```



The World is the most central node, with those nearest to the world being the population sampling and data generation processes.

These results may suggest that lowering bias in ML, and in the World, could come from multiple actors, targeting different parts of the graph, with the same goals.