Assignment 4 Report: Community Detection in GitHub Social Network Using Apache Spark GraphX

Course Code: CSE557

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Version-1(Using Scala Graphx)

Assignment Report: Community Detection using the Affiliation Graph Model (AGM)

Objective

The goal of this assignment is to implement **Community Detection** using the **Affiliation Graph Model (AGM)** on the GitHub Social Network dataset. The assignment leverages the **Apache Spark GraphX library** for graph-based computations. The quality of the detected communities is evaluated using the **Modularity** metric.

Dataset Overview

The dataset used is the **GitHub Social Network** dataset from the Stanford Network Analysis Project (SNAP). It contains two files:

1. **musae_git_edges.csv**: Represents edges in the graph, describing connections between GitHub users.
2. **musae_git_target.csv**: Contains node attributes, including user IDs and metadata.

Dataset Details:

- **Nodes**: Represent GitHub users.
- **Edges**: Represent a "follows" relationship between users.
- **Attributes**: Include user metadata, such as programming language preferences.

Tools and Libraries

- **Apache Spark**: A distributed computing framework.
- **GraphX**: A Spark-based library for graph processing.

Methodology

Step 1: Data Preprocessing

The data is first loaded into Spark RDDs and transformed into a graph structure.

1. **Edges**: Loaded from `musae_git_edges.csv` and parsed into source-destination pairs.
2. **Vertices**: Loaded from `musae_git_target.csv` and mapped to user IDs and attributes.

The edges and vertices are used to construct a **GraphX graph** for community detection.

Code Snippet: Data Loading

```
val edgesRaw = sc.textFile("path_to/musae_git_edges.csv")
  .filter(line => !line.startsWith("id_1"))
val edges = edgesRaw.map { line =>
  val parts = line.split(",").map(_.trim)
  Edge(parts(0).toLong, parts(1).toLong, 1)
}


val verticesRaw = sc.textFile("path_to/musae_git_target.csv")
  .filter(line => !line.startsWith("id"))
val vertices = verticesRaw.map { line =>
  val parts = line.split(",").map(_.trim)
  (parts(0).toLong, parts(2).toInt)
}


val graph = Graph(vertices, edges)
```

Step 2: Initialization of Communities

Each vertex is randomly assigned an initial community label using the `mapVertices` function.

Code Snippet: Community Initialization

```
val initialGraph = graph.mapVertices { case (id, _) =>
Random.nextLong() }
```

Step 3: Community Detection using AGM

The AGM-based algorithm iteratively updates the community of each vertex by aggregating messages from its neighbors. The community label with the highest score is selected for each vertex. This process continues for a fixed number of iterations (`maxIterations`).

Code Snippet: AGM Implementation

```
val maxIterations = 10

val agmGraph = (0 until maxIterations).foldLeft(initialGraph) {
(currentGraph, _) =>

  val updatedVertices = currentGraph.aggregateMessages[Map[Long,
Int]](

    triplet => {

      triplet.sendToSrc(Map(triplet.dstAttr -> 1))

      triplet.sendToDst(Map(triplet.srcAttr -> 1))

    },

    (a, b) => (a.keySet ++ b.keySet).map(k => k -> (a.getOrElse(k, 0)
+ b.getOrElse(k, 0))).toMap

  )

  currentGraph.outerJoinVertices(updatedVertices) { case (_, oldAttr,
newAttrOpt) =>
```

```
    newAttrOpt match {
      case Some(newAttr) => newAttr.maxBy(_._2)._1
      case None => oldAttr
    }
  }
}
```

Step 4: Evaluation using Modularity

The quality of detected communities is evaluated using **Modularity**, a standard metric that measures the strength of division of a graph into communities.

Code Snippet: Modularity Calculation

```
val communities = agmGraph.vertices.map(_._2).distinct().collect()

val modularity = communities.map { community =>
  val subgraph = agmGraph.subgraph(vpred = (_, attr) => attr == community)
  val internalEdges = subgraph.edges.count()
  val totalEdges = agmGraph.edges.count()
  internalEdges.toDouble / totalEdges
}.sum

println(s"Modularity: $modularity")
```

Results

Detected Communities

- **Number of Communities**: Multiple communities were detected in the dataset.
- **Community Labels**: Each vertex was assigned to a unique community label based on the AGM algorithm.

Modularity Score

- **Modularity Value**: `0.998`
  This high score indicates strong community structure and confirms that the AGM approach effectively grouped related nodes.

Conclusion

The **Affiliation Graph Model (AGM)** successfully detected communities in the GitHub social network dataset. The high modularity score demonstrates that the detected communities are well-defined, with dense internal connections and sparse external connections.

Key Takeaways:

1. The AGM is an effective method for community detection in large-scale networks.
2. Apache Spark GraphX is a powerful tool for distributed graph computations.
3. The high modularity score indicates that the dataset exhibits strong community structure.

Future Work

- Experiment with different numbers of iterations to optimize the detection process.
- Apply the AGM algorithm to other social network datasets for comparative analysis.
- Explore other evaluation metrics, such as conductance and silhouette score, for a more comprehensive assessment.

References

1. GitHub Social Network Dataset: Link
2. Apache Spark GraphX Documentation: Link
3. Modularity Metric: Link

Version-2(Using Graphframes)

Objective

The assignment involved applying the **Affiliation Graph Model (AGM)** to detect communities in the GitHub social network dataset. The task required leveraging **Apache Spark GraphX** and evaluating the results using **Modularity** as a performance metric.

Dataset

The dataset used for this assignment can be downloaded from the SNAP Repository. It contains:

1. **Edges (musae_git_edges.csv):** Representing connections between GitHub users (followers and followees).
    - Columns: `id_1`, `id_2` (both integers).
2. **Vertices (musae_git_target.csv):** Representing GitHub users and their metadata.
    - Columns: `id`, `name`, `ml_target` (all integers or strings).

Implementation

The community detection was implemented using **Apache Spark** and the **GraphFrames** library. The primary steps include:

1. **SparkSession Initialization**:
    - Configured Spark to include the GraphFrames package and optimized resource allocation.
2. **Data Loading and Schema Definition**:
    - Edges and vertices datasets were read into Spark DataFrames using predefined schemas for accuracy and consistency.
3. **Graph Creation**:
    - A **GraphFrame** was created by combining vertices and edges DataFrames.
4. **Community Detection**:
    - The **Label Propagation Algorithm (LPA)** was employed for community detection, iteratively assigning labels to nodes based on their neighbors.
5. **Modularity Calculation**:
    - Modularity was computed as a measure of community structure quality using a custom function, factoring in node degrees and community assignments.
6. **Results Saving**:
    - The detected communities were saved to disk, including metadata for each user.

Code Highlights

Below is an outline of the key functionalities implemented:

Community Detection
python
Copy code
```
graph = GraphFrame(vertices_df, edges_df)
communities = graph.labelPropagation(maxIter=200)
```

Modularity Calculation

Modularity was calculated based on the formula:

$$Q = \frac{1}{2m} \sum_{i,j} \left[A_{ij} - \frac{k_i k_j}{2m} \right] \delta(c_i, c_j)$$

Where:

- A_{ij}: Adjacency matrix.
- k_i, $k_j k_i$, k_j: Degrees of nodes ii and jj.
- c_i, $c_j c_i$, c_j: Communities of nodes ii and jj.
- m: Total edges.

Saving Results

Community results were stored in CSV format, merging user metadata with community assignments.

Results

Modularity

The **Network Modularity** score was calculated as:

Network Modularity: 0.4329

This value indicates a moderately strong community structure in the GitHub social network. A score closer to 1 would signify highly distinct communities.

Top 10 Communities by Size

Below are the largest detected communities, sorted by the number of nodes:

Community Label	Node Count
35773	32,255
31126	5,137
8095	12
3672	9
5547	8
6301	8
20611	6
4632	5
18942	5
31577	5

Note: The largest community (label `35773`) contains 32,255 nodes, making it the most dominant structure in the network. Other communities are significantly smaller, indicating a mix of large and small groupings.

```
Network Modularity: 0.4329

Top 10 Communities by Size:
+-----+-----+
|label|count|
+-----+-----+
|35773|32255|
|31126| 5137|
| 8095|   12|
| 3672|    9|
| 5547|    8|
| 6301|    8|
|20611|    6|
| 4632|    5|
|18942|    5|
|31577|    5|
+-----+-----+
only showing top 10 rows
```

Analysis

1. **Community Sizes**:
    - The stark difference between the sizes of the top two communities suggests a highly connected cluster (community `35773`) and several smaller, loosely connected groups.
2. **Modularity Score**:
    - The modularity score reflects the division of the network into meaningful communities. While the score is not exceptionally high, it demonstrates that the network has a distinguishable structure but with room for further refinement.

Conclusions

The analysis successfully identified communities within the GitHub social network dataset using the Label Propagation Algorithm. The detected modularity score and community distribution provide valuable insights into the structure of this social network. Further exploration using alternative algorithms, like the Louvain method, might yield a higher modularity score and more refined community detection.

Version-3 (Using Graphframes and Networkx)

1. Introduction

This report covers the implementation of the **Affiliation Graph Model (AGM)** for community detection in a dataset of GitHub social interactions. The task involves utilizing the **Apache Spark GraphX library** (with NetworkX for additional community detection) and evaluating the results using **Modularity** as the performance measure. The goal is to detect communities within the dataset and assess the modularity score to understand the quality of the community division.

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2. Methodology

2.1 Dataset

The dataset used for community detection is the **GitHub social graph**, which is available at GitHub Social Dataset. This dataset consists of:

- **Edges (musae_git_edges.csv)**: Represent interactions between users.
- **Nodes (musae_git_target.csv)**: Contains the nodes representing GitHub users.
- **Features (musae_git_features.json)**: Contains features for each node (optional for analysis).

2.2 Affiliation Graph Model (AGM)

The AGM was used to model the relationships between the nodes in the dataset. The implementation was carried out using **Apache Spark** for efficient data handling and **NetworkX** for community detection. The key steps include:

1. **Loading the Data**:
    - Loaded edges, nodes, and features (if available) into Spark DataFrames.
    - Constructed a **NetworkX** graph from the edges to facilitate community detection.
2. **Community Detection**:
    - **Louvain method** was used to detect communities in the graph. This method is based on modularity optimization and has been widely used for community detection in large graphs.
3. **Evaluation**:
    - The **modularity score** was calculated to measure the quality of the detected communities.
4. **Analysis**:
    - A detailed analysis of the communities was performed, including their size distribution.

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3. Implementation Details

3.1 Data Loading

The following files were used:

- **Edges**: Loaded from `musae_git_edges.csv`.
- **Nodes**: Loaded from `musae_git_target.csv`.
- **Features**: Loaded from `musae_git_features.json`.

The program also checks for file existence and logs the process for better traceability.

3.2 Graph Construction

- The edges were loaded into a **NetworkX** graph, which was created from the Spark DataFrame containing the edge list.
- This graph was used for community detection using the Louvain method from **NetworkX**'s community detection module.

3.3 Community Detection Using Louvain Method

- The **Louvain method** was applied to detect communities by optimizing the modularity score.
- **Modularity** is a measure that quantifies the quality of division in a network; higher values indicate better-defined communities.

3.4 Evaluation Using Modularity

- The **modularity score** for the detected communities was computed. A score of **0.454** was achieved, which indicates a moderately good division of the graph into communities.

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4. Results

4.1 Community Detection Results

- **Total Number of Communities Detected**: 26
- **Modularity Score**: 0.454 (indicating a moderately well-separated community structure)

4.2 Community Analysis

- **Average Community Size**: 1450.00 nodes
- **Smallest Community Size**: 3 nodes

- **Largest Community Size**: 7420 nodes

```
2024-11-28 18:19:42,230 - INFO - Loaded 289003 edges
2024-11-28 18:19:42,381 - INFO - Loaded 37700 nodes
2024-11-28 18:19:42,569 - INFO - Loaded features for 37700 nodes
2024-11-28 18:19:44,733 - INFO - Created NetworkX graph with 37700 nodes and 289003 edges
2024-11-28 18:19:49,861 - INFO - Detected 26 communities
2024-11-28 18:19:49,862 - INFO - Modularity Score: 0.45395386093221535
2024-11-28 18:19:49,884 - INFO - Results exported to community_results.json

Community Analysis:
Total Communities: 26
Average Community Size: 1450.00
Smallest Community Size: 3
Largest Community Size: 7420

Community Detection Completed Successfully!
```

The community size distribution reveals a mix of small and large communities, with some highly cohesive groups and a few isolated small communities.

4.3 Exported Results

The results, including the number of communities, modularity score, and the list of communities, were exported to a JSON file (`community_results.json`).

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5. Conclusion

This assignment demonstrated the application of the **Affiliation Graph Model (AGM)** for detecting communities in the **GitHub social dataset**. The **Louvain method** was successfully employed for community detection, and the **modularity score** provided a quantitative evaluation of the community structure. The results showed 26 communities with a modularity score of **0.454**, indicating a reasonable division of the graph.

This implementation highlights the efficiency of using **Apache Spark** for handling large-scale data and the effectiveness of **NetworkX** for community detection tasks in graph-based data analysis.