JOHANNES KEPLER UNIVERSITÄT LINZ

Algorithms and Data Structures 2
Winter term 2021
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Assignment 04

Deadline: **Tue. 21.12.2021, 23:59**

Graphs

Please don't change any skeleton we provide. Of course, you are allowed to add code (methods and global variables), as long as you don't break the skeleton (method names and variables' types) we need for the unit tests to work correctly. **Please remember to fill out the time log survey in Moodle.**

1. Graphs and their terminology 4+1+1+1+3=10 points

Please solve the following exercises using **pen & paper**.

For the parts where you have to use digits of your student ID: **k12345678, d1 = 1, d2 = 2, …, d8 = 8 (if one of the digits is 0, use 1 instead)**

1. Given the following adjacency matrix, add an edge from d2 to d3 with edge weight d4 (overwriting existing edges if needed), insert d6 to d8 of your student ID as edge weights, **draw the corresponding graph** (incl. edge weight – if you want, you can use a graph drawing engine such as DOT/Graphviz*****) and **answer the following questions**:
   a. Is the graph weighted (yes / no)?
   b. Is it directed (yes / no)?
   c. Which vertex / vertices has / have the highest in-Degree (vertex id)?
   d. Which vertex / vertices has / have the highest out-Degree (vertex id)?
   e. What is the largest edge weight (number)?
   f. Is the graph cyclic (cyclic / acyclic)?
   g. How many loops are there (number)?
   h. Is the graph connected (no / weakly / strongly)?
   i. Is the graph a tree (yes / no)?

   ***** DOT/Graphviz visualization template:
   https://dreampuf.github.io/GraphvizOnline/#digraph%20G%20%7B%0A%20%20%20%201-%3E2%20%5Blabel%3D5%5D%0A%20%20%20%202-%3E3%20%5Blabel%3D10%5D%0A%20%20%20%20%23%20...%0A%7D

   Adjacency matrix:

from/to	1	2	3	4	5	6	7	8	9
1		5		4					
2	5		5	1					
3				d6	d7	d8			
4							1		
5								2	
6									1
7								4	
8									4
9									

2. Draw a complete undirected graph with at least 5 vertices.
3. Draw an undirected graph with at least 3 components, where each vertex has at least a degree of 2.
4. Draw a cyclic directed graph with at least 4 vertices, where at least one vertex is not part of the cyclic path.
5. Perform a DFS on the following graph. If one of your student ID digits would cause a duplicate in the graph, append an asterisk to the digit (i.e., d6 = 2 and would be a duplicate, then d6 = 2*). Asterisk numbers come after their respective non-asterisk numbers (i.e., 2* comes after 2 but before 3 in ascending order). Start DFS at 1 and take notes on each step: current node - adjacent nodes (ascending) - next node (smallest adjacent or "up") - visited nodes

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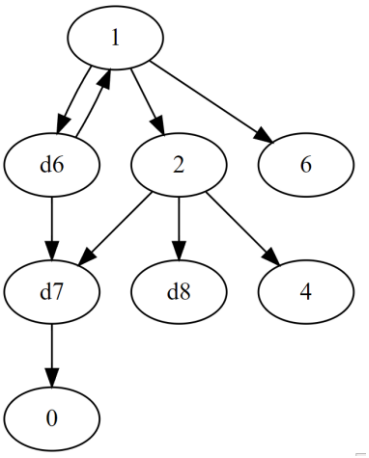
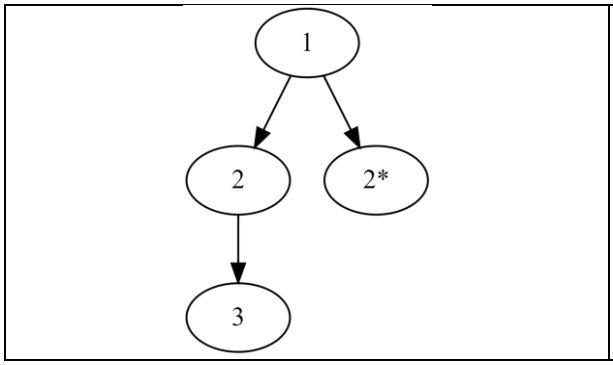


Example:




```
1 -     [2,2*] - 2      - [1]
2 -     [3]    - 3      - [1,2]
3 -     []     - 2(up)  - [1,2,3]
2 -     [3]    - 1(up)  - [1,2,3]
1 -     [2,2*] - 2*     - [1,2,3]
2* -    []     - 1(up)  - [1,2,3,2*]
1 -     [2,2*] - end    - [1,2,3,2*]
```

2. Graph implementation using an Edge List — 14 points

Implement an **undirected, weighted** graph without loops using an **edge list**. Instances of the class `Vertex` represent a vertex in a graph, instances of the class `Edge` represent undirected, weighted edges between two vertices. The graph itself has to be defined in the class `Graph` by you, don't change the given method declarations. **Make sure to provide a working implementation, since you will need a working graph implementation for assignment 5 (shortest path algorithms).**

```
class Vertex():
    def __init__(self, index, name=""):
        self.idx = index   # index at which the vertex has been added
        self.name = name   # name of the vertex
```

```
class Edge():
    def __init__(self, first_vertex, second_vertex, weight):
        self.first_vertex = first_vertex   # reference to a vertex
        self.second_vertex = second_vertex   # reference to a vertex
        self.weight = weight               # weight of the edge
```

```
from vertex import Vertex
from edge import Edge


class Graph():
    def __init__(self):
    self.vertices = []  # list of vertices in the graph
    self.edges = []  # list of edges in the graph
    self.num_vertices = 0
    self.num_edges = 0
    self.undirected_graph = True
```

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```
    def get_number_of_vertices(self):
        """
        :return: the number of vertices in the graph
        """
        # TODO

    def get_number_of_edges(self):
        """
        :return: the number of edges in the graph
        """
        # TODO

    def get_vertices(self):
        """
        :return: list of length get_number_of_vertices() with the vertices of the graph
        """
        # TODO

    def get_edges(self):
        """
        :return: list of length get_number_of_edges() with the edges of the graph
        """
        # TODO

    def insert_vertex(self, vertex_name):
        """
        Inserts a new vertex with the given name into the graph.
        Returns None if the graph already contains a vertex with the same name.
        The newly added vertex should store the index at which it has been added.

        :param vertex_name: The name of vertex to be inserted
        :return: The newly added vertex, or None if the vertex was already part of the graph
        :raises: ValueError if vertex_name is None
        """
        # TODO

    def find_vertex(self, vertex_name):
        """
        Returns the respective vertex for a given name, or None if no matching vertex is found.
        :param vertex_name: the name of the vertex to find
        :return: the found vertex, or None if no matching vertex has been found.
        :raises: ValueError if vertex_name is None.
        """
        # TODO

        def insert_edge_by_vertex_names(self, v1_name, v2_name, weight: int):
        """
        Inserts an edge between two vertices with the names v1_name and v2_name and returns the newly
        added edge. None is returned if the edge already existed, or if at least one of the vertices is
        not found in the graph.
        A ValueError shall be thrown if v1 equals v2 (=loop).
        :param v1_name: name (string) of vertex 1
        :param v2_name: name (string) of vertex 2
        :param weight: weight of the edge
        :return:  Returns None if the edge already exists or at least one of the two given vertices is
                  not part of the graph, otherwise returns the newly added edge.
        :raises: ValueError if v1 is equal to v2 or if v1 or v2 is None.
        """
        # TODO

        def insert_edge(self, v1: Vertex, v2: Vertex, weight: int):
        """
        Inserts an edge between two vertices v1 and v2 and returns the newly added edge.
        None is returned if the edge already existed, or if at least one of the vertices is not found in
        the graph.
        A ValueError shall be thrown if v1 equals v2 (=loop).
        :param v1: vertex 1
        :param v2: vertex 2
        :param weight: weight of the edge
        :return: Returns None if the edge already exists or at least one of the two given vertices is
not part of the                graph, otherwise returns the newly added edge.
        :raises: ValueError if v1 is equal to v2 or if v1 or v2 is None.
        """
        # TODO
```

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```
    def find_edge_by_vertex_names(self, v1_name, v2_name):
        """
        Returns the edge if there is an edge between the vertices with the name v1_name and v2_name,
otherwise None.
        In case both names are identical a ValueError shall be raised.
        :param v1_name: name (string) of vertex 1
        :param v2_name: name (string) of vertex 2
        :return: Returns the found edge or None if there is no edge.
        :raises: ValueError if v1_name equals v2_name or if v1_name or v2_name is None.
        """
        # ODO

    def find_edge(self, v1: Vertex, v2: Vertex):
        """
        Returns the edge if there is an edge between the vertices v1 and v2, otherwise None.
        In case v1 equals v2 a ValueError shall be raised.
        :param v1: vertex 1
        :param v2: vertex 2
        :return: Returns the found edge or None if there is no edge.
        :raises: ValueError if v1 equals v2 or if v1 or v2 are None.
        """
        # TODO


    def get_adjacency_matrix(self):
        """
        Returns the NxN adjacency matrix for the graph, where N = get_number_of_vertices().
        The matrix contains the edge weight if there is an edge at the corresponding index position,
        otherwise -1.
        :return: adjacency matrix
        """
        # TODO


    def get_adjacent_vertices_by_vertex_name(self, vertex_name):
        """
        Returns a list of vertices which are adjacent to the vertex with name vertex_name.
        :param vertex_name: The name of the vertex to which adjacent vertices are searched.
        :return: list of vertices that are adjacent to the vertex with name vertex_name.
        :raises: ValueError if vertex_name is None
        """
        # TODO


    def get_adjacent_vertices(self, vertex: Vertex):
        """
        Returns a list of vertices which are adjacent to the given vertex.
        :param vertex: The vertex to which adjacent vertices are searched.
        :return: list of vertices that are adjacent to the vertex.
        :raises: ValueError if vertex is None
        """
        # TODO
```

Submission

Put your source files and a pdf for part 1 into a ZIP archive and name the file **k12345678-assignment04.zip** where k12345678 should reflect your student ID.