COMP9024 Assigment 4

This is the design manual of COMP9024 Assignment 4.

In this assignment, a digraph is used to represent a bus network and several functions are implemented to explore its feature.

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Data Structures

Graph Structures

- `BusStops`

  This structure stores bus stop names and bus stop serial numbers, according to assignment spec bus stop names are no longer than 20 characters.

  ```
  typedef struct bus_stop{
    char name[20];        // bus name is no more than 20 characters
    int id;               // serial number of a bus stop
  }BusStop;
  ```

  Go to appendix to see its relationship with other structures.

- `Edge`

  An edge links two vertices with a given distance. In this structure we only need to specify the destination vertex and distance, because `Edge` is designed to be the subclass of `vertex` so the source vertex is just the vertex itself.

  Unfortunately circular dependency exists between `Edge` and `Vertex` (they mutually define each other !), to resolve this issue it is important to declare : `struct vertex;` before we define `Edge`

  ```
  struct vertex;            // declare vertex beforehand
  typedef struct edge{
    struct vertex *dst;     // destination vertex
  ```

```
  int distance;          // the length of the edge
}Edge;
```

Go to appendix to see its relationship with other structures

- `Vertex`

  A vertex must hold information of a bus stop as well as its corresponding edges. In `Vertex` we used `List` to store edges (named `edgesQueue`) as well as reversed edges (named `reversed_edgesQueue`). Reversed edges tell which vertices can reach this vertex and how far they are from this vertex, `reversed_edgesQueue` is useful in `StronglyConnectivity` where we need to apply dfs reversely. Variables `distanceFromStartVertex`, `previousVertexInShortesPath`,`positionInHeap` are useful in Dijkstra's Algorithm. `isMark` is a book-keeping variable to ensure that in BFS or DFS no vertex is accessed more than once.

```
typedef struct vertex{
  BusStop *thisBusStop;
  struct list *edgesQueue;
  struct list *reverse_edgesQueue;
  struct vertex *previousVertexInsShortestPath;
  int distanceFromStartVertex;
  int positionInHeap;         // the position of the vertex in binary
heap
  int isMarked;
}Vertex;
```

  Go to appendix to see its relationship with other structures

- `Graph`

  A graph is just a collection of vertices and edges. Since edges are already stored in their corresponding vertice, there's need to explictly declare them in `Graph` again. Maximum number of vertices, current number of vertices and edges are saved in `Graph` for book-keeping.

```
typedef struct graphRep{
  Vertex **vertices; // store an array of vertex pointer
  int size;          // max number of vertices that can be store in
graph
  int nV;            // number of vertices currently stored in graph
  int nE;            // number of edges currently stored in graph
}GraphRep;
typedef GraphRep *Graph;
```

  Go to appendix to see its relationship with other structures

All structures disscussed in this section are defined in `MyGrap.h`

List Structures

- `ListNode`

  `List` is mainly used in storing edges of graph. Hence a `ListNode` contains a pointer that points to an edge.

  ```
  typedef struct list_node{
    struct edge *thisEdge;
    struct list_node *next;
  }ListNode;
  ```

  Go to appendix to see its relationship with other structures

- `List`

  In addtion to the first node of the list, last node of the list is also cached in `List`, which makes it possible to append a node to `List` in O(1) time, regardless of how long the list is.

  ```
  typedef struct list{
    ListNode *firstNode;
    ListNode *lastNode;
    int size;
  }List;
  ```

  Go to appendix to see its relationship with other structures

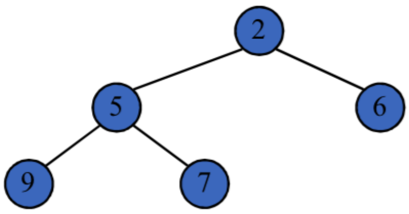
All structures disscussed in this section are defined in `MyList.h`.

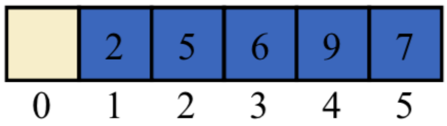
Heap Structure

To implememt Dijkstra's algorithm a heap structure is indispensable. The basic idea is to store every vertex in a heap, ordered by it's distance from the start point. For each run we take the smallest vertex out of the binary heap and compute relaxation until the heap is empty.

```
typedef struct binary_heap{
    struct vertex **node;  // the vertex pointers of graph are all stored
in an array
    int n;                 // current number of nodes
    int size;              // total number of nodes
}BinaryHeap;
```

Inside the binary heap, vetices are store in an array. Below example depicts how an array represents binary heap:





Notice that array at position 0 is unused.

Go to appendix to see its relationship with other structures

Algorithms

- Depth-first Search (DFS)
  - used in `StronglyConnectivity` to search all bus stops that can be reached
- Breadth-first Search (BFS)
  - used in `reachableStops`
- Kosaraju's Algorithm
  - used in `maximalStonglyComponents`
- Dijkstra's Algorithm
  - used in `TravelRoute` to find shortest path

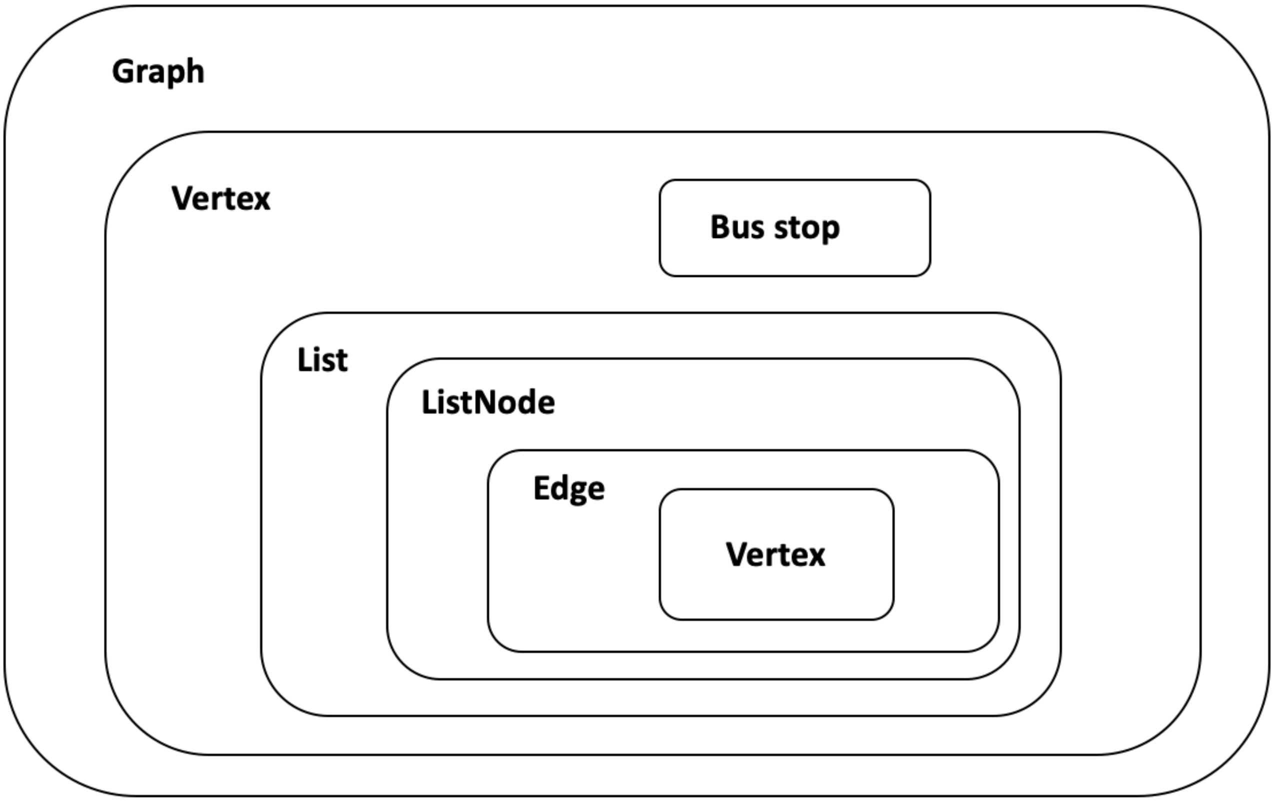
Time Complexity Analysis

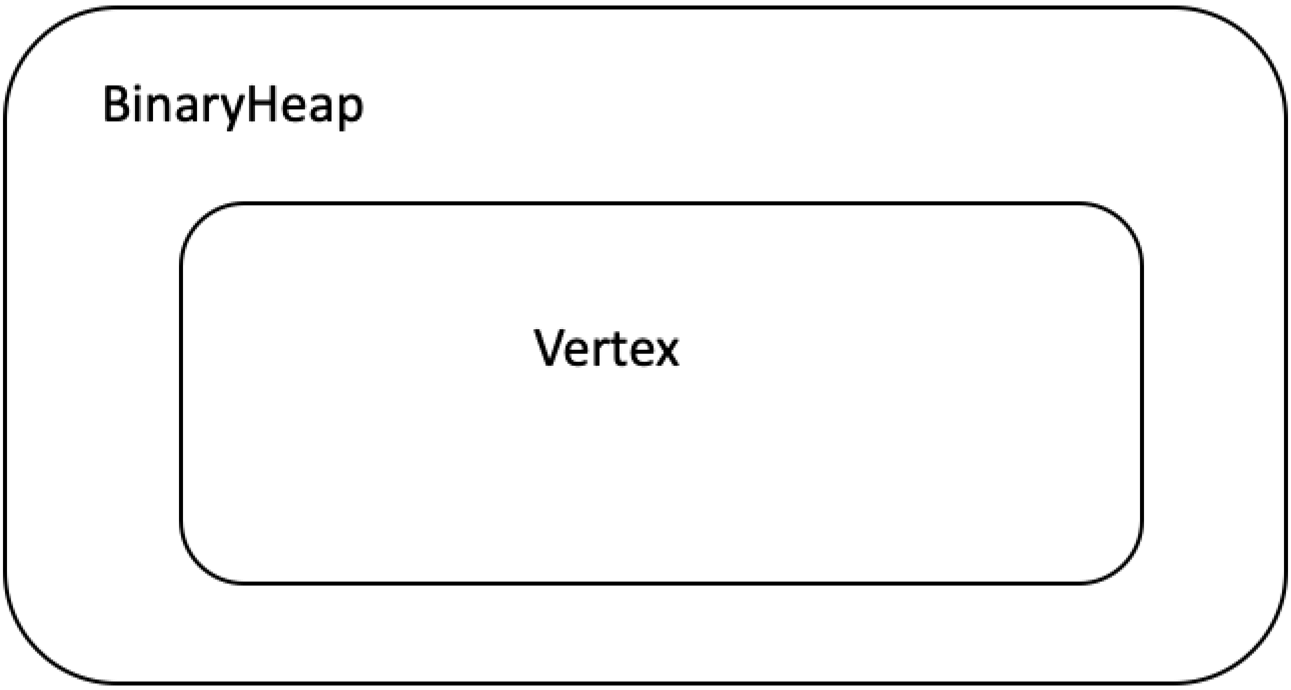
Function name	Time complexity
`StronglyConnectivity`	O(M+N)
`maximalStronlyComponents`	O(M+N)
`reachableStops`	O(M+N)
`TravelRoute`	O((M+N)*logN)

Appendix

Structures Dependencies

Diagram below depicts the relationship between different structures, if structure A encloses structure B then structure B is the subclass of structure A (aka, there is a B declared in A).


Graph
Vertex
Bus stop
List
ListNode
Edge
Vertex


BinaryHeap
Vertex