Water Supply Management System

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

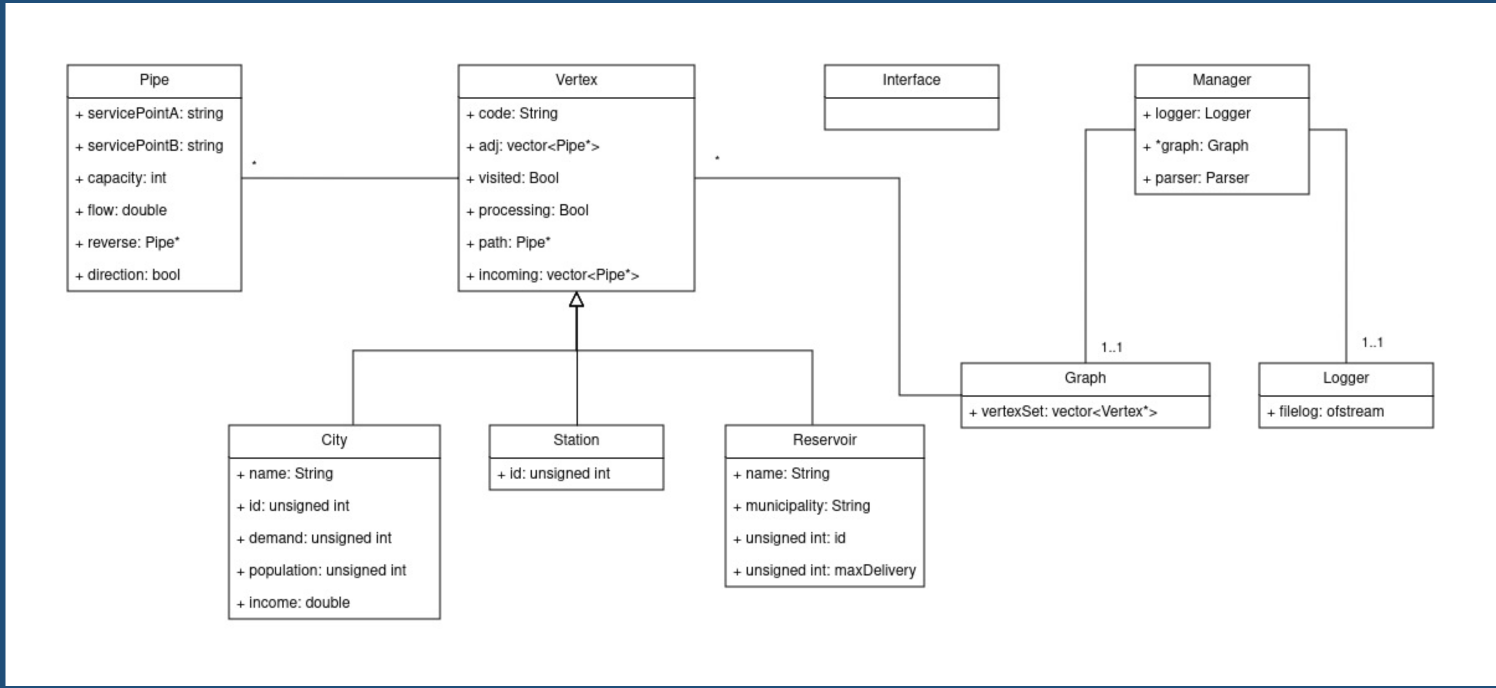
Nuno Machado | Rafael Magalhães | Ricardo Oliveira
GROUP G15_5

Project Overview

UML Class Diagram

Each class is divided into:

- **`.h file`** – declares the class, the class variables and methods;
- **`.cpp file`** – contains the implementation of the functions of the respective .h file.



Water Supply Manager Class diagram

Dataset Reading

> Data of the pipes, cities, reservoirs and stations.

`small (Madeira)`

or

`large (Portugal)`

User input →

```
pipes.csv
cities.csv
reservoirs.csv
stations.csv
```

Parser →

Graph

```
graph->addCity();
graph->addReservoir();
graph->addStation()
graph->addEdge();
```

Graph Representation

vector<Pipe*> adj

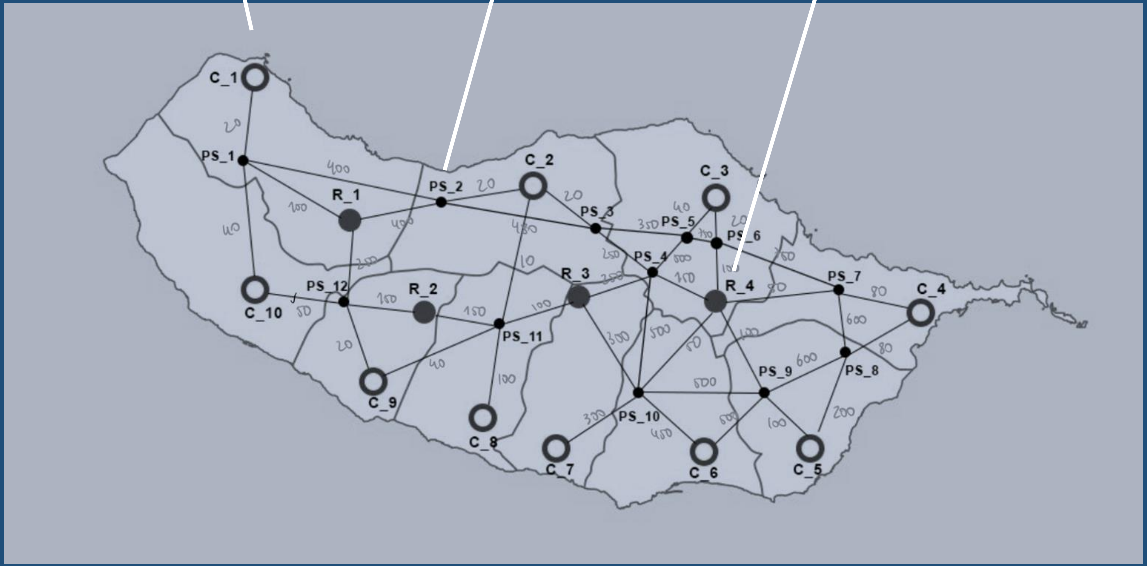
Pipe*
Pipe*

vector<Vertex*> vertexSet

City*	Station*	Reservoir*

- This structure allows a more efficient use of memory allowing quicker attribute updating and protects against object slicing.

- Each point in the graph is considered a Vertex, and each connection between them is a Pipe.

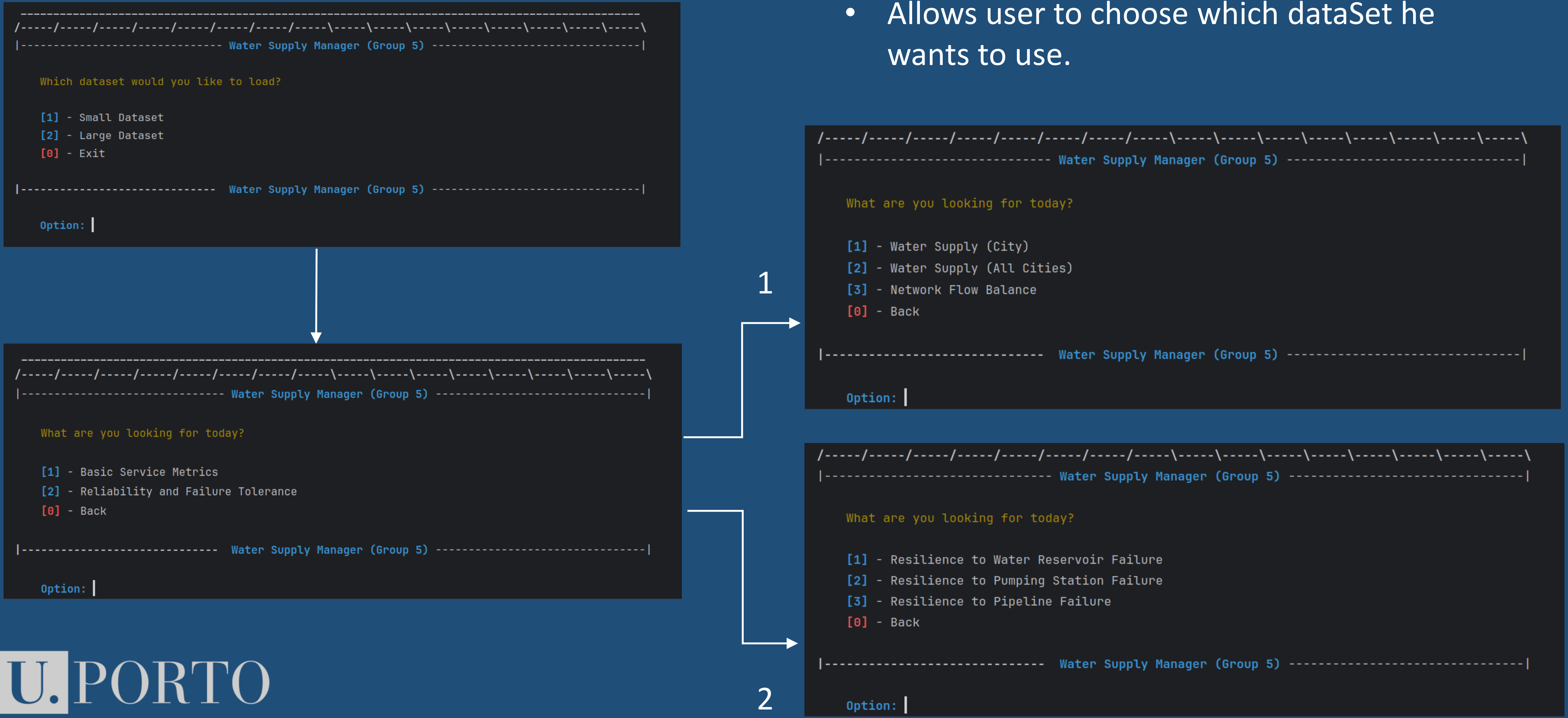


Small DataSet example.

Implemented Features and Demonstration

User Interface

- Allows user to choose which dataSet he wants to use.



U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

Implemented Features

Basic Service Metrics:	Concepts and algorithms related to graphs	Time Complexity
Water Supply (Single City)[1]	Edmonds Karp Adaptation	$O(V * P^2)$
Water Supply (All Cities)[1]	Edmonds Karp Adaptation	$O(V * P^2)$
Network Flow Balance	Edmonds Karp Adaptation	$O(V * P^2)$

```
        Insert a city code (e.g. C_1):C_4
 C_4


| Code          | Demand        | Supply        | Status        | Deficit       | Name
| C_4           | 137           | 137           | SUPPLIED      | 0             | Machico


                        < Press ENTER to Continue >
```

MaxFlow single city example

```
| Code      | Demand    | Supply    | Status        | Deficit   | Name
| C_1       | 18        | 18        | SUPPLIED      | 0         | Porto Moniz
| C_2       | 34        | 34        | SUPPLIED      | 0         | S├úo Vicente
| C_3       | 46        | 46        | SUPPLIED      | 0         | Santana
| C_4       | 137       | 137       | SUPPLIED      | 0         | Machico
| C_5       | 295       | 295       | SUPPLIED      | 0         | Santa Cruz
| C_6       | 740       | 664       | NOT SUPPLIED  | 76        | Funchal
| C_7       | 225       | 225       | SUPPLIED      | 0         | C├ómara de Lobos
| C_8       | 89        | 89        | SUPPLIED      | 0         | Ribeira Brava
| C_9       | 59        | 59        | SUPPLIED      | 0         | Ponta do Sol
| C_10      | 76        | 76        | SUPPLIED      | 0         | Calheta


Total Flow: 1643


                    < Press ENTER to Continue >
```

MaxFlow all cities example

V: Number of vertexes
P: Number of Pipes

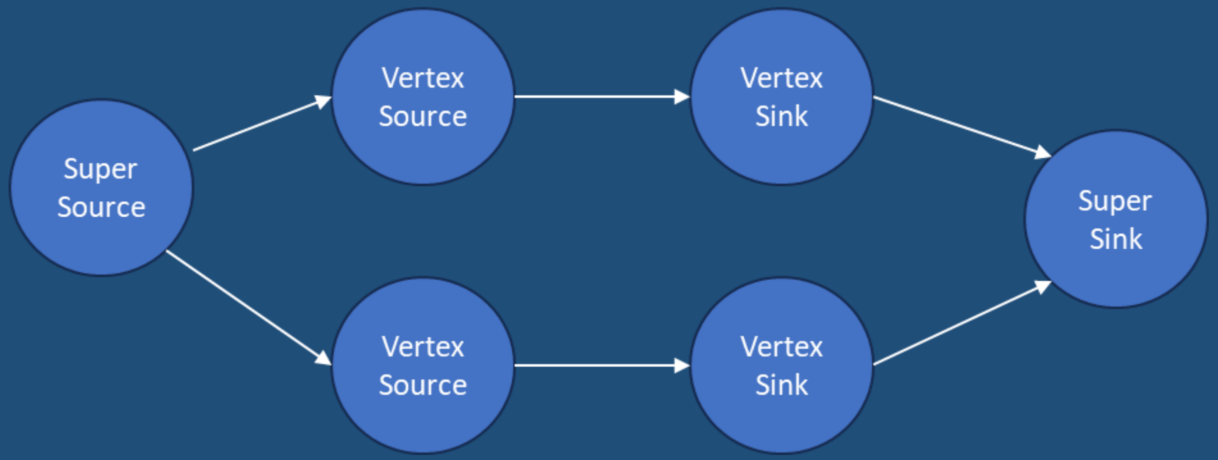
[1] Output é também escrito num ficheiro de log.

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

Implemented Features: Basic Service Metrics

- In a multi-source and sink graph, super sources and super sinks simplify the calculation of maximum flow.

- These are new nodes that connect to all original sources or sinks, respectively. By introducing them, the graph is transformed into a single-source and single-sink graph, making it easier to apply standard maximum flow algorithms, in this case, the Edmonds-Karp.



Illustrative example

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

Implemented Features

Balance Flow

- Finds the largest path from the super source to the super target using breadth-first search while considering the minimum residual capacity.

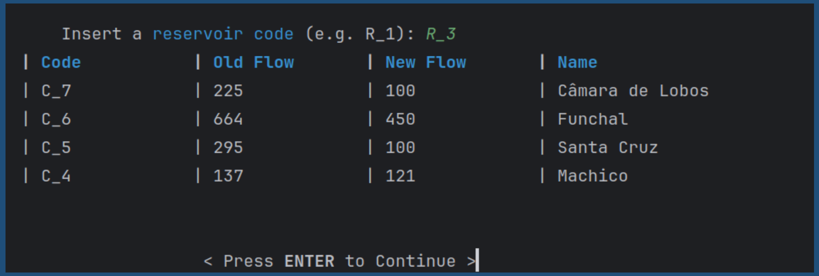
- Along this path, it computes the minimum residual capacity, indicating the maximum flow that can be added without violating constraints, and augments the flow accordingly.

- After each iteration, the algorithm dynamically adjusts the minimum residual capacity parameter. Once the termination condition is met, it computes flow balance and removes the added super vertices.

- This approach balances flow in the network by iteratively finding paths with the largest capacity potential.

Implemented Features

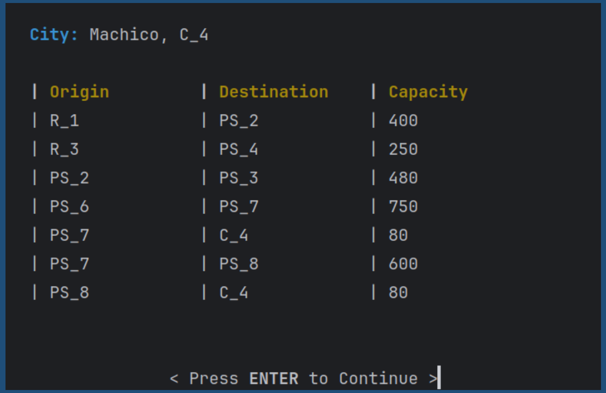
Reliability and Failure Tolerance	Concepts and algorithms related to graphs	Time Complexity
Resilience to Water Reservoir Failure	Max-Flow	$O(V * P^2)$
Resilience to Pumping Station Failure	Max-Flow	$O(V * P^2)$
Display Cities affected by Pipe	Max-Flow	$O(V * P^2)$
Display Pipes Vital to City	Max-Flow	$O(V * P^3)$


Insert a reservoir code (e.g. R_1): R_3

Code	Old Flow	New Flow	Name
C_7	225	100	Câmara de Lobos
C_6	664	450	Funchal
C_5	295	100	Santa Cruz
C_4	137	121	Machico

< Press ENTER to Continue >

Reservoir Failure Example


City: Machico, C_4

Origin	Destination	Capacity
R_1	PS_2	400
R_3	PS_4	250
PS_2	PS_3	480
PS_6	PS_7	750
PS_7	C_4	80
PS_7	PS_8	600
PS_8	C_4	80

< Press ENTER to Continue >

Vital pipes for City example

V: Number of vertexes
P: Number of Pipes

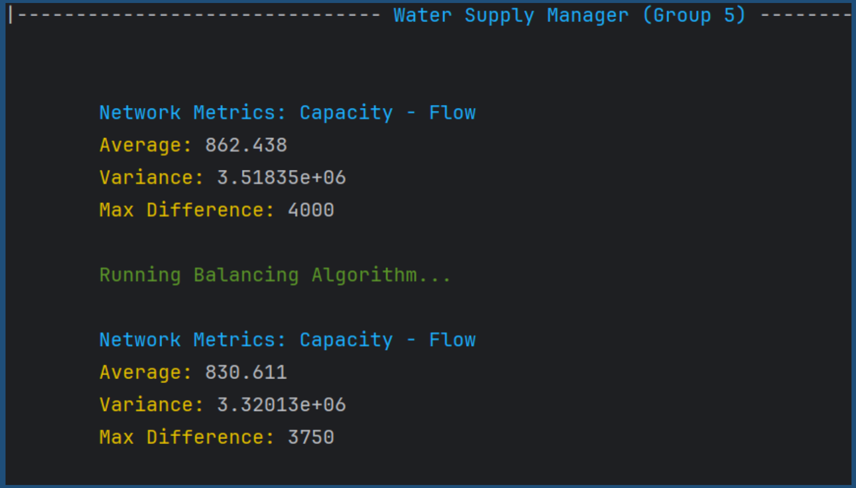
U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

Practical Demonstration

Conclusion

Highlights

- Using a structure with a vertex set of Vertex*, where other vertices derive from, provides advantages in terms of memory efficiency, quicker attribute updating, enabling polymorphic behavior, and avoiding object slicing. This design choice can lead to more flexible and efficient graph manipulation and algorithms.



Balancing algorithm improving metrics

Difficulties and Participation

Difficulties

- Finding an appropriate data representation that suited the problem.
- The balance flow algorithm.

Participation

- Each team member contributed significantly to different phases of the project, collectively trying to overcome these challenges.

Water Supply Management System

U.PORTO

FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

Nuno Machado | Rafael Magalhães | Ricardo Oliveira
GROUP G15_5

April, 2024