

DEVELOPMENT OF A GRAPH DYNAMIC SECTORIZATION TOOL USING QGIS/POSTGRESQL TO PLAN AND OPERATE WATER DISTRIBUTION NETWORKS

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Abstract

This paper presents a definition of different types of sectorization used by water distribution companies, as well as a methodology for their identification and application in the dynamic zoning of water distribution networks.

The graph model of large water supply networks is made up of thousands or hundreds of thousands of nodes and pipelines, as well as valves, tanks, pumps and pressure groups. Its generation from the data contained in a GIS does not report difficulty with the currently existing tools, the GISWATER module of QGIS is an example of this. Problems arise when these models have to be operated from a high number of conditions and scenarios. To facilitate the operability of the system, one of the strategies is to simplify its operation through topological analysis. One of the proposals is clustering where the nodes belonging to a cluster have more and better connections with the internal nodes than with the external ones.

Our work analyses water distribution networks from five different points of view, which it represents five sector classes according to the parameter analysed. As result, one of them, the District Metering Area (DMA) delimited by headers (flowmeters) and stoppers (other flowmeters or closed valves), is extensively covered in the literature. The other four, less common in the literature, have a definition equivalent to that of the DMA but based on other class of headers and stoppers. Therefore, if we are looking to operate the network from the point of view of pressure, we can use the dynamic sectorization algorithm by configuring Tanks, Head pumps, flow pumps, PSV, PBV or PRV as headers.

Moreover, to operate and analyse the network from the point of view where water comes from, we can use again the dynamic algorithm by configuring the inlets of the system as headers (Tanks and Reservoirs).

On the other hand, if the goal is to be focused on water quality, the algorithm can be configured using chlorinators, chlorinators, water treatment equipment or water sources as headers.

Finally, special attention deserves the minimum sector which represents the minimum structural unit of the network, defined by the region covered by network where there are shutoff-valves on their borders. In order to operate water networks as optimized as possible, the status of shut-off valves is dynamic. The opening and closing of valves allow a continuous reconfiguration of the network and the classes or types of sectors defined.

As result, to analyse the network graph using this approach enables the water operator to analyse the best status as possible as well as it is amazing scenario to analyse resilience of network using stochastics methods.

Keywords

Sectorization, dynamic zoning, network, DMA, minimum structural unit.

1 INTRODUCCION

Water management has always been complex and expensive. It has always been difficult to plan new water supply networks or effectively control existing ones without making further capital investments. Nonetheless all these situations have come to an end.

Since 2014 when Giswater [1] was born, it has been the first open-source software specifically designed for water supply and water management. This software connects different IT solutions and pre-existent databases allowing you to setup a high-performance management system in combination with hydraulic software as well EPANET [2] or SWMM [3].

In order to facilitate the operability of the system, one of the strategies is to simplify its operation through topological analysis. One of the proposals consists of clustering [4] where the nodes belonging to a cluster have more and better connections with the internal nodes than with the external ones.

This work has been developed using Open-Source software from the ecosystem of Giswater environment. For this specific algorithm you can access to the full source code on Github [5].

2 NETWORK MAPZONES

INLET SECTOR (I-SECTOR)

Network subgraph defined as subgraph area limited by inlets (Tank or Reservoir). It is the minimum unit for hydraulic calculation since it contains the water supply. Flow meters or pressure meters are not considered. pressure reducing valves and pressure groups are not considered.

On the INLET-SECTOR (I-SECTOR) there are no customers. Only exists water transportation from some point to another point.

SUPPLY SECTOR (S-SECTOR)

Network subgraph defined as subgraph area limited by inlets (Tank or Reservoir) and closed valves with customers which they consume water. As well as [I-SECTOR] it is also the minimum unit for hydraulic calculation by exporting some EPANET file since it contains the water supply.

Flow meters or pressure meters are not considered. pressure reducing valves and head pumps are not considered,

DISTRICT METER AREA(DMA)

Network subgraph defined as subgraph area limited by meters and closed valves. It is the subgraph unit to make measurements of water balances for network. It enables the possibility to calculate water losses and Not Revenue Water (NRW).

PRESSURE SECTOR (PRESSZONE)

Network subgraph defined as subgraph area limited by pressure regulation elements (Tank, Reservoir, PSV, PRV, PBV, Pump) and closed valves. It is the subgraph used to calculate the static pressure as maximum pressure for the whole system.

DISTRICT QUALITY AREA (DQA)

Network subgraph defined as subgraph area limited by quality regulation and quality measurement elements (Tanks, Reservoirs or chlorinators) and closed valves. It is the subgraph used to define quality water areas. It enables to calculate the residence time and the evolution of the water quality parameters.

Moreover, network subgraph defined as subgraph area limited by shut-off valves. It is the minimum network affected in case of breakdown. It shows the minimum number of clients affected by the supply interruption due to the breakdown. Also enables the breakdown probability calculation. This subgraph is called **minimum sector** and can provide also amazing analysis for each one of those five functional mapzones defined above.

3 NETWORK AND GRAF DELIMITERS

Drinking water network has several elements which some of them establish hierarchy and also work between each other. That can give many opportunities to the organization from a functional and system analysis point of view.

In order to analyse water distribution networks from different functional points of view, we need to built-up the graph and define which network elements acts as graph objects and which acts are delimiters.

Regarding network graph will be built-up by using topologic data from arc and node table (*arc_id*, *node_1* and *node_2*). This information is stored on *temp_anlgraf* table which is the core table for this algorithm in combination with the *fact_gw_grafanalytics_mapzones* function.

id	arc_id	node_1	node_2	water	flag	checkf	length	cost	value	trace	isheader	orderby
[PK] serial	character varying(20)	character varying(20)	character varying(20)	smallint	smallint	smallint	numeric(12,4)	numeric(12,4)	numeric(12,4)	integer	boolean	integer

Figure 1. Columns for *temp_anlgraf* table

Moreover, headers and stoppers are defined below:

Storage tanks. Modifies the residence time of the water in the system. They act as graph delimiter for [I-SECTOR] [S-SECTOR].

Supply and storage tanks. Establishes a pressure or primary supply level for one or more customer sectors and modifies its residence time of water in the system. They act as graph delimiter for [I-SECTOR] [S-SECTOR].

Queue tanks. Establishes a secondary supply level for a sector of customers and modifies the residence time of the network water. In fact, they are not graph delimiter because they are by themselves end-point of system.

Supply and queue tanks. Queue tanks, establishes primary and secondary supply level at the same time for two or more customer sectors and modifies the residence time of water in the network. They may act as graph delimiter for [S-SECTOR].

Flow meters. Determines the differential flow in the first case and integral flow in the second case, by a specific synchrony. They act as graph delimiter for [DMA].

Pressure reduce, sustain and break valves. Modifies the pressure and supply level downwards. It is generally associated with customer sectors but not exclusively. They act as graph delimiter for [PRESSZONE].

Head pump. Modifies upwards the pressure and supply level to a sector of clients. It has a small storage (pilot whale) that usually should not be considered, since the storage time is usually lower than the measurement frequency of the flow meters. They act as graph delimiter for [PRESSZONE].

Pumping station. Water transfer between two storage points with increase of elevation. They act as graph delimiter for [PRESSZONE].

Quality measurement elements. Quality measurement elements like chlormeter. They act as graph delimiter for [DQA].

Quality regulator. Quality regulator like chlorinator. They act as graph delimiter for [DQA].

Shut-off valves. Is an actuated valve designed to stop the flow upon the detection of a dangerous event or some other operation. This provides protection against possible harm to people, equipment or the environment. They act as graph delimiters for all the different mapzones in function of they are open or closed.

Unique customers. Customers with a very high or unique consumption in their behaviour. They should be treated as specific nodes.

4 DYNAMIC ZONIFICATION ALGORITHM

One of the main characteristics of this algorithm is that it is executed on server side. It means that the whole code is stored into PostgreSQL database and QGIS client only acts as user interface.

As a result, with this algorithm, the five different types of zonifications described before are ready-to-execute. To work with, this mapzones algorithm can be executed after completing the configuration process which means that:

- Populate the *graf_delimiter* column on *cat_feature_node* table with values defined above on network graph delimiters chapter.
- Populate the *grafconfig* column on mapzones table (*sector, dma, dqa, presszone*). Syntax is a bit special but allows every possible cardinality (multiple nodeParent with multiple toArc for a single mapzone).

In case that nodes whose *node_type* is a graph delimiter and has not been named as the head of any mapzone, the system will allow the calculation but will give a warning. Since this is a possible option (transport tanks or queue tanks without a specifically defined *node_type*) it is advisable to use the "ignore" key of the *grafconfig* field so that at least the system does not give warnings of elements that we have clear and checked.

Once configured it is moment to trigger the algorithm. The workflow of the algorithm it is simple.

It starts an inundation process from headers by flooding the network, tracing element by element stopping in front of other headers or in front of closed shut-off valves.

This inundation process is done by *gw_fct_grafanalytics_mapzones* function by using a simple loop. In order to control the process on each loop, algorithm updates columns *water* and *trace* on *temp_anlgraf* table. Column *water* to know when one node has been processed or not and column *trace* to know which is the *node_id* of the header. Besides these two objects (*gw_fct_grafanalytics_mapzones* and *temp_anlgraf*) one relation more on PostgreSQL database is used on this process. This is the *view v_anl_grafanalytics_mapzones*.

Moreover, code side, algorithm has a well-structured user side. By using dialog showed below user can choose the graph class analysis as well as other parameters for their analysis.

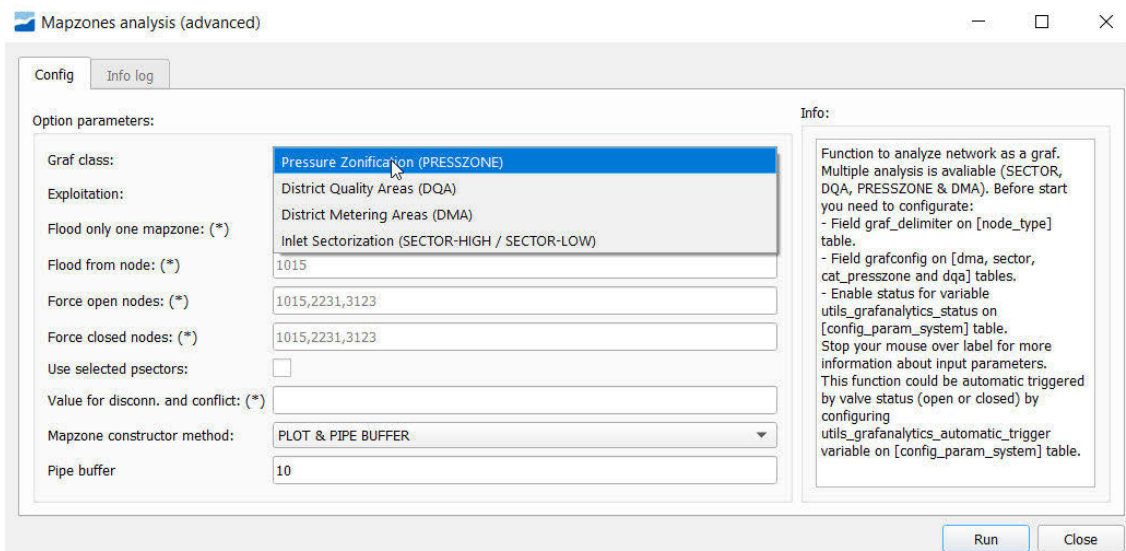


Figure 2. Dialog on QGIS user interface for input parameters before trigger algorithm

In fact, several parameters can be passed when function is triggered. Table on below shows all parameters and additional information about description, example data and range of values:

Table 1. Detailed information about the parameters accepted for algorithm

PARAMETER	DESCRIPT	EXAMPLE	RANGE OF VALUES
grafClass	Graph class to perform	DMA	DMA, SECTOR, DQA, PRESSZONE
exploitation	Exploitations to participate in the algorithm	[1,2]	All the available exploitations
updateFeature	If true, update the values of dma_id, presszone_id, sector_id & dma_id of all NODES, ARCS, CONNEC that are flooded by the algorithm	true	false, true
updateMapZone	0: does not update the geometry field (the_geom) of the mapzone 1: Updates by making an enveloping polygon with all the elements 2: Updates by buffering the pipes with the value of geomParamUpdate 3: Updates by buffering the pipes with the value of geomParamUpdate and incorporating the plot geometry (if it exists) 4: Updates by buffering the pipes with the value of geomParamUpdate and incorporating the link geometry (if it exists) 5: Updates by buffering the pipes with the value of geomParamUpdate and incorporating some customized geometry (if it exists)	2	0,1,2,3,4,5
geomParamUpdate	Value related to options 2, 3 of the previous key. It is the value of the buffer (expressed in meters)	10	Any float 0.1 - 100
macroExploitation	Not mandatory value. Useful to define macro-exploitations to participate in the algorithm. In case of not null value this will be prioritized against exploitation key	[1,2]	All available macro-exploitations
checkData	Not mandatory value. If true, check if the system data is correct (topology, state_type, etc), and in case of errors, this will abort the process.	false	false, true
usePlanPsector	Not mandatory value. If true, the selected sectors from user will be used by the analysis of the algorithm.	false	false, true
floodOnlyMapzone	Not mandatory value. If not null, algorithm only will flood defined mapzones.	[1,2]	All defined mapzones
valueForDisconnected	Not mandatory value. If not null, disconnected elements will take another value different from 0. This is useful when you are building your sectorization model.	1	All mapzone values
forceOpen	Not mandatory value. Valves that can be forced to open (e.g. for closed valves that we want to open for whatever reason)	[1,2,3]	All closed valves
forceClosed	Not mandatory value. Nodes in general that can be forced to close (e.g., in the debug phase in case the trace gets out of control and does not converge as expected)	[1,2,3]	All nodes (except closed valves)

Once function is finished returns a detailed log about executed process. This log provides information about possibly conflicts against mapzones, disconnected elements as well as the number of elements affected, in terms of pipes, nodes and connects.

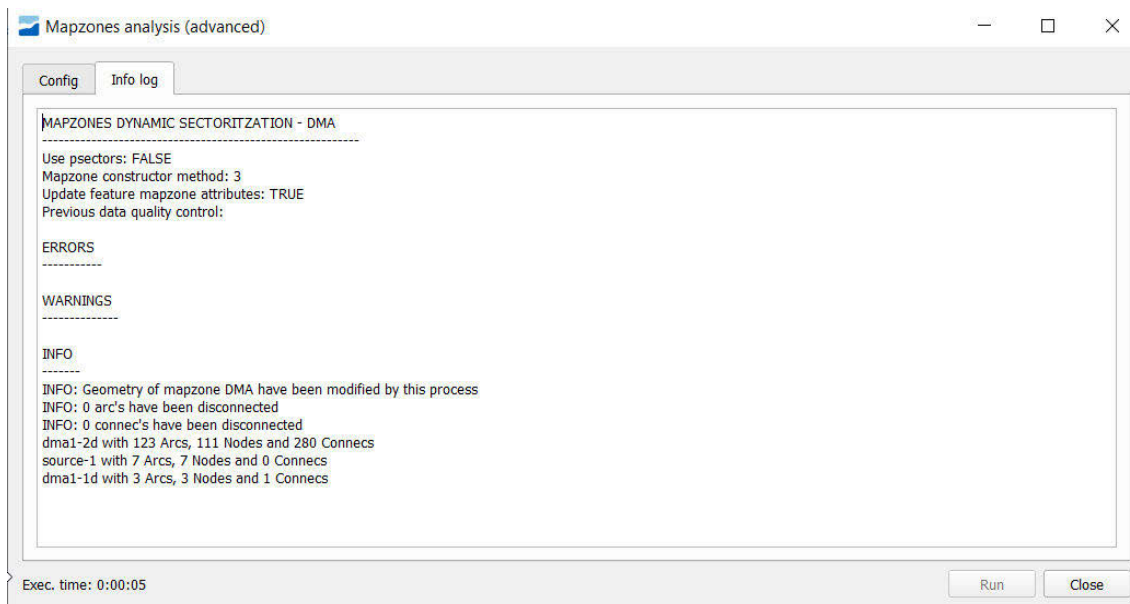


Figure 3. Dialog on QGIS user interface for output log after trigger algorithm

One of the most interesting input parameters is 'updateMapZone' which allows user to represent the mapzone on map by four different ways.

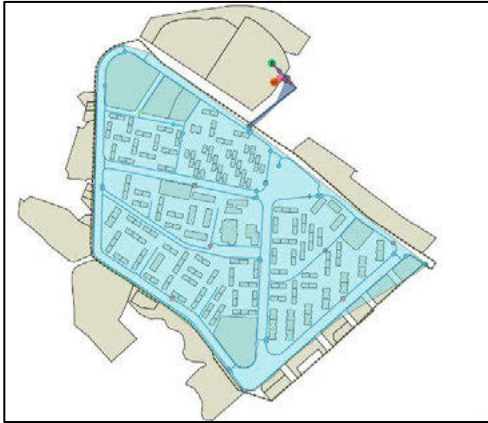


Figure 4. Mapzone geometry by polygon envelope

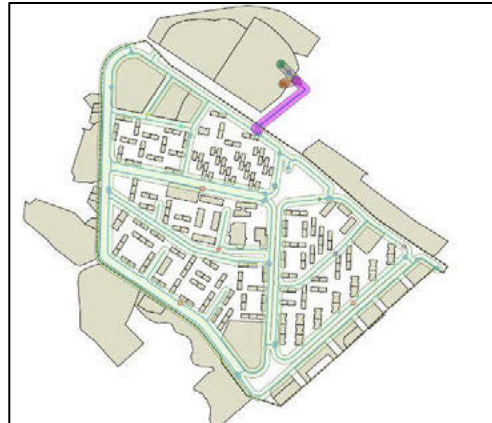


Figure 5: Mapzone geometry by pipe buffer

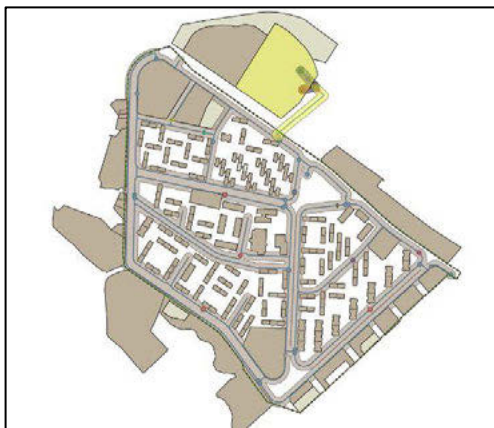


Figure 6. Mapzone geometry by pipe buffer and plot.



Figure 7: Mapzone by pipe and link buffer

Once algorithm finish a detailed log is showed for user in order to provide as much information as possible for the obtained result

5 ENHANCEMENT OF WATER NETWORK ANALYSIS USING EPANET

One of the most interesting issues applying this methodology is the enhancement of network analysis by using EPANET.

As you know this tool have been developed into the Giswater ecosystem. Giswater project is natively oriented to integrate GIS inventory data with US EPA hydraulic programs EPANET & SWMM. From version 1.0 launched on 2014, database was already designed to full-integration of inventory and hydraulic modelling capabilities. As a result, there are some special issues that makes Giswater as powerful tool to integrate hydraulic capacities with asset inventory.

The impact of this dynamic graph analytics on EPANET analytics is huge because it enhances several issues.

In terms of the mapzone SECTOR, this is the minimum unit to generate EPANET files. It is possible to generate as many sectors as you like but at least one. In fact, the definition of sector comes natively from EPANET. Sector is what EPANET needs, at least with one INLET, one pipe and one junction.

In terms of PRESSZONE, it could be useful to calibrate and to check EPANET water analytics because this mapzone provides us information about the static pressure which is the maximum pressure could be supplied

Regarding of DMA, it is very useful because brings us the possibility to make water balances by using this tool as well as it is possible to use composed patterns for in-side junctions on each DMA by composing patterns using timestep water balances from inlet meters less outlet meters.

Finally, DQA is less used than other mapzones, but the logic is also the same.

6 CONCLUSIONS

The work presented applies in a real network, methodologies described on the literature for different types of functional analysis for water distribution networks.

The key point of this work is how we have managed to harmonize and structure the functional analysis of a water network based on the objective that we are pursuing, [INLET, WATER BALANCE, OPERATION ZONE, QUALITY AREAS] always oriented to the analysis needed.

Future works can go on giving more performance to the algorithm with the use of the minimum sector described in section 2 of this paper as a unitary element of network graph in spite of work with node and arcs objects.

7 ACKNOWLEDGEMENTS

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8 REFERENCES

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