Comparing severe transport situations

Similarity or reduction methods

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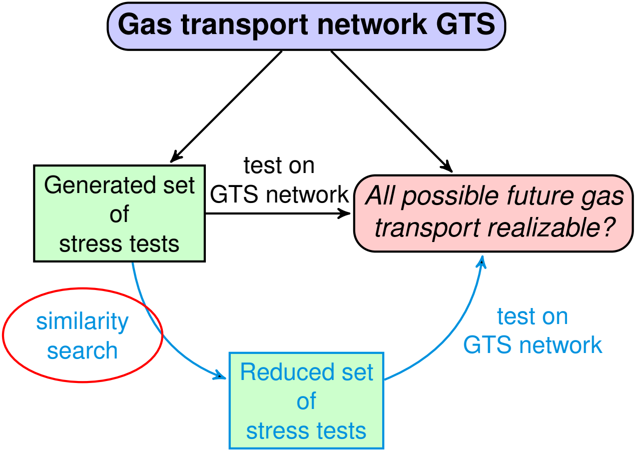
Gasunie Transport Services

Responsible for the management, the operation and the development of the national transmission grid

- Sufficient transport capacity
- Security of supply
- Quality conversion
- Balancing the grid

Aim of my project



Gas transport network GTS

Generated set of stress tests

test on GTS network

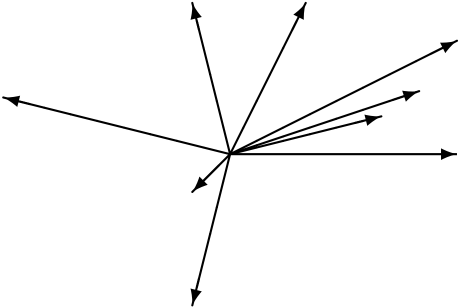
All possible future gas transport realizable?

similarity search

Reduced set of stress tests

test on GTS network

Stress tests



Stress test

- vector
- *n*-dimensional
- balanced
- correlated dimensions

↕

mutual distances
& capacities

No Euclidean space

Quadratic form distance

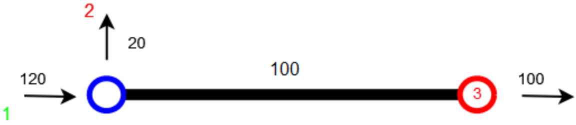
Quadratic form distance

$$QFD_{\mathbf{A}}(u, v) = \sqrt{(u - v)^T \mathbf{A}(u - v)}$$

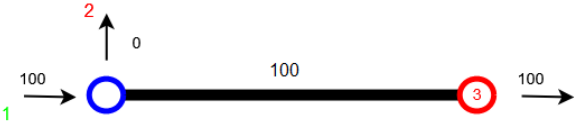
Conjecture definition **A**

$$\mathbf{A}_{ij} = 1 - \frac{d_{ij}}{d_{max}}$$

Quadratic form distance - Example matrix

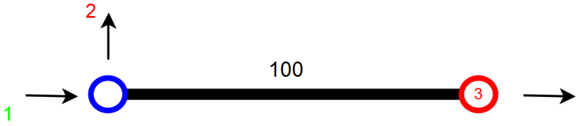


$$u = \begin{pmatrix} 120 \\ -20 \\ -100 \end{pmatrix}$$



$$v = \begin{pmatrix} 100 \\ 0 \\ -100 \end{pmatrix}$$

Quadratic form distance - Example matrix



$$d_{max} = 100$$

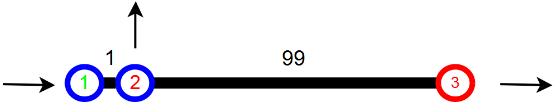
$$[d_{ij}] = \begin{array}{c|ccc} & 1 & 2 & 3 \\ 1 & 0 & 0 & 100 \\ 2 & 0 & 0 & 100 \\ 3 & 100 & 100 & 0 \end{array}$$

$$\mathbf{A} = \begin{array}{c|ccc} & 1 & 2 & 3 \\ 1 & 1 & 1 & 0 \\ 2 & 1 & 1 & 0 \\ 3 & 0 & 0 & 1 \end{array}$$

$$u = (120, -20, -100)^T$$
$$v = (100, 0, -100)^T$$
$$u - v = (20, -20, 0)^T$$

$$QFD = 0$$

Quadratic form distance - Example matrix



$$d_{max} = 100$$

$$[d_{ij}] = \begin{array}{c|ccc} & 1 & 2 & 3 \\ \hline 1 & 0 & 1 & 100 \\ 2 & 1 & 0 & 99 \\ 3 & 100 & 99 & 0 \end{array}$$

$$\mathbf{A} = \begin{array}{c|ccc} & 1 & 2 & 3 \\ \hline 1 & 1 & 0.99 & 0 \\ 2 & 0.99 & 1 & 0.01 \\ 3 & 0 & 0.01 & 1 \end{array}$$

$$u = (120, -20, -100)^T$$
$$v = (100, 0, -100)^T$$
$$u - v = (20, -20, 0)^T$$

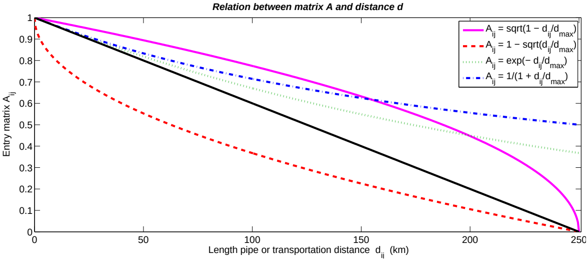
$$QFD = \sqrt{8} \approx 2.83$$

$$||u||_{\mathbf{A}} \approx 141.73$$
$$||v||_{\mathbf{A}} \approx 141.42$$

Quadratic form distance - Definitions matrix

Definitions $\mathbf{A}_{ij}$

- $\sqrt{1-\frac{d_{ij}}{d_{max}}}$
- $1-\sqrt{\frac{d_{ij}}{d_{max}}}$
- $\exp\left(-\frac{d_{ij}}{d_{max}}\right)$
- $\frac{1}{1+\frac{d_{ij}}{d_{max}}}$



Quadratic form distance - Metric

Is the QFD indeed a distance/metric?

A **semi-norm** $||.|| : \mathbb{R}^n \rightarrow \mathbb{R}$, is a function satisfying:

(1) $||cu|| = |c| \cdot ||u||$ for all scalars $c \in \mathbb{R}$, $u \in \mathbb{R}^n$

(2) $||u + v|| \leq ||u|| + ||v||$ for all vectors $u, v \in \mathbb{R}^n$

$$||u - v|| = \sqrt{(u - v)^T \mathbf{A}(u - v)}$$

The matrix **A** needs
to be positive semidefinite

Positive semidefinite on a subspace

- Stress tests are balanced gas transport situations
- Difference of two stress tests is balanced as well
- So, for a difference vector **x** the following holds

$$\sum_i x_i = 0$$

- Consider the correlation matrix **A** or distance matrix **D** on this subspace

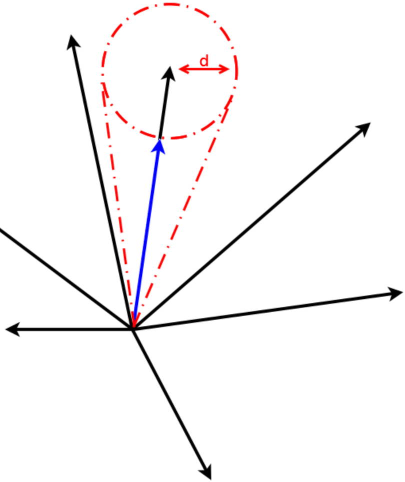
Positive semidefinite on a subspace

- Not for the ‘original’ definition

$$\mathbf{A}_{ij} = 1 - \frac{d_{ij}}{d_{max}}$$

- Probably for the definition, which is based on the diameter as well

Reducing steps



Reducing steps

1. Start with the vector with the greatest length, say x.
2. Calculate the angle φ between this vector x and the boundary of its cone.
3. Determine the angle θ between this vector x and the other vectors in the set.

Reducing steps

4. Apply the condition $\theta \leq \varphi$, to determine which vectors lie within the cone of x. These vectors are called almost similar to x.
5. Delete these vectors, which are almost similar to this longest vector x, from the set.
6. Consider the next longest vector y ($y \neq x$) of the remaining set, and apply steps 2 - 6 till the remaining set is empty.

Concluding remarks

Table 1: An overview of the conclusions regarding the QFD.

Criteria	**1.** Physical characteristics of the gas transport network	Probably
	2. Distinction between different stress tests	Yes
	3. Threshold value relates to the ‘generating inaccuracy’ of 10 dam^3/h	Yes
	4. Tuning the parameters	Yes → matrix **A**

Concluding remarks

Table 2: An overview of the conclusions regarding the QFD.

Criteria	**5.** The need to use specific transport physics of the gas network	Low
	6. Similarity, when a stress test is less severe than the other	Yes, considering the angle φ
	7. Applicable for stress tests depending on blending load	Not examined

Concluding remarks

Future research

- Test reducing steps on the detailed network of GTS
- Reconsider the posed reducing algorithm:

  does this algorithm results in a minimal set?
- Involve the blending load with respect to stress tests

Thank you all

Questions ?