Subproject A04

TRR 154

Mathematical modeling, simulation, and optimization using the example of gas networks

Combinatorial Switching for Routing Gas Flows

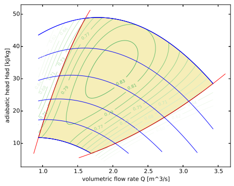
Benjamin Hiller Caren Tischendorf Tom Walther

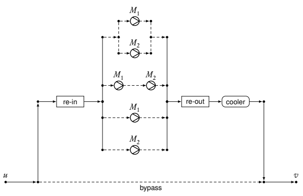
Konrad-Zuse-Zentrum für Informationstechnik Berlin
www.zib.de

Summary

The goal of this project is to develop algorithmic foundations for the efficient treatment of switching decisions in gas networks and, in particular, in compressor stations. The focus is on the treatment of nonconvex sets that can be represented as the union of polyhedra. Therefore, based on the geometric properties of such a set, we will develop a hierarchic (i.e., recursively refined) description that delivers a polyhedral relaxation as accurate as possible on each hierarchy level.

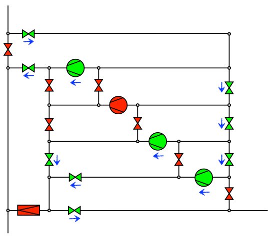
As a starting point for our investigations, we use so-called characteristic diagrams of individual compressor machines that describe their physical and technical capabilities.





We then aim at finding aggregated polyhedral representations of the capabilities of compressor groups, i.e., collections of compressors that can be operated in several possible configurations.

Finally, we intend to develop an integrated treatment of complex compressor stations connecting several pipeline systems and containing multiple compressor groups, based on higher-dimensional polyhedral representations of their operating range.

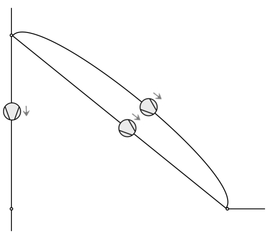


Analysis of operation modes

⇒ **Goal:** Build refined model of operation modes that allows to compute tighter relaxations for each of these

- bound propagation
- topology simplification
- classification

⇝ simplified representation of each operation modes showing its precise flow and compression pattern

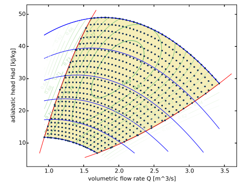


⇒ **Computational results:**

	compact model	extended model	bounded extended model
number of binary variables after presolve	29.6 / 33.5	34.1 / 33.2	27.6 / 33.2
number of solving nodes	9.2 / 16.3	10.4 / 24.4	11.1 / 20.5
presolving detected infeasibility	– / 80.4%	– / 80.1%	– / 84.2%

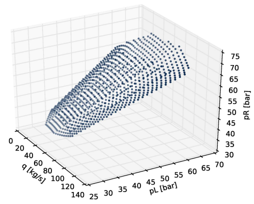
Compressor model simplification

The most detailed descriptions of compressor machine capabilities in characteristic diagrams involve nonlinear dependencies that are undesirable in the context of optimization procedures. We therefore develop simple, yet still accurate, compressor models.



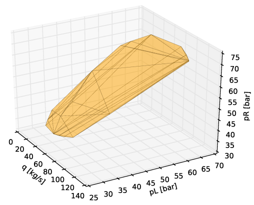
Step 1

Generate sample points in the space of volumetric flow rate Q and the specific change in adiabatic enthalpy H_{ad}. Due to nonlinear relations, we want to avoid working in this space.



Step 2

Project sample points into the space of mass flow rate q and inlet- and outlet pressures p^{in} and p^{out}. It suffices to project points of the characteristic diagram boundary.



Step 3

Compute convex hull of the feasible sample points in (q, p^{in}, p^{out}) w.r.t. to compressor drive restrictions. Apply facet reduction algorithm for 'smaller' convex hull representation.

Approximate Convex Decomposition

The aggregated operating ranges of compressor groups and stations can be represented by nonconvex sets originating from the union of polyhedra. For the purposes of optimization, we aim at finding near-convex decompositions of these sets using hierarchical so-called Approximate Convex Decomposition methods (LIEN [2006]).

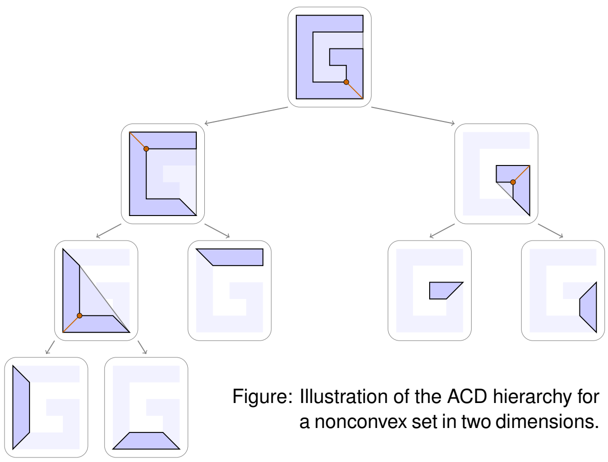


Figure: Illustration of the ACD hierarchy for a nonconvex set in two dimensions.

- implementation of 2D variant of ACD is relatively easy
- technical issues for extension to 3D

⇒ **Goal:** Develop generalised ACD algorithm in dD, $d > 3$

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
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