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Pooling Problem: Modeling, Global Optimization and Computational Studies Survey

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The pooling problem, an optimization challenge of maximizing profit subject product availability, storage capacity, demand, and product specification constraints, has applications to petroleum refining, wastewater treatment, supply-chain operations, and communications. This review illustrates the long-standing symbiosis between the economic challenge of optimally combining feed stocks into products and therefore the mathematical field of worldwide optimization. We present five sub-classes of pooling problems: standard pooling, generalized pooling, extended pooling, nonlinear blending, and petroleum operations as representative industrial challenges. We also discuss solution techniques: successive applied mathematics, the worldwide optimization algorithm GOP and other Lagrangian-based approches, the reformulation-linearization technique (RLT), and piecewise-affine underestimation within the context of the pooling problem.

Final products during an oil refinery are created by combining feed stocks emerging from distillation units, reformers, and catalytic crackers. The input feed stock streams, which have varying chemical compositions and physical properties, are sent to common tanks or pools before being mixed into products. The mixtures in these intermediate pools are blended with additives like ethanol to make a plethora of ultimate products, like three grades of gasoline, diesel oil, aviation jet fuel, and fuel oil.

The challenge of maximizing profit subject to product availability, storage capacity, demand, and merchandise specification constraints are often explicitly formulated as an optimization problem. Recognizing the worth in process optimization, Exxon used applied mathematics as early because the 1950s to enhance blending schemes. The target of those linear models, just like the more physically-accurate nonlinear models that followed, was maximizing profit subject to product specific constraints. Blending feed stocks became tougher within the 1970s as recognition of environmental and health hazards limited the octane-enhancing additive tetra-ethyl lead. in additional recent years, the Environmental Protection Agency (EPA) has, in accordance with the Clean Air Act of 1990, enforced reductions in smog-forming volatile organic compounds (VOC) and nitrous oxides (NOX).

These environmental standards, including limited availability of low-sulfur crude and new automobiles requiring high octane fuels [14], inspired extensive research into the pooling problem. The pooling problem involves a feed-forward topology and a group of restrictions on the chemical and physical properties of the products. The network contains a group of input nodes, representing the feed stock supply, a group of intermediate nodes, symbolizing the pools, a group of output nodes, denoting the ultimate products, and a topology of inter-node connections, representing possible flows.

When the intermediate nodes are unnecessary (i.e., feed stocks are directly blended into final products) and therefore the product properties are often calculated using flow–weighted averaging of the feed stocks (i.e., linear blending applies), the optimization problem are often expressed as a linear program (LP). However, monitoring pool composition requires nonconvex bilinear and, for giant scale problems with pools serial, trilinear terms, making the matter a nonlinear program (NLP).

The pooling problem nonconvexities, which prevent linear, convex, and stochastic solvers from certifying global optimality, inspired extensive research into the sector of worldwide optimization. Conversely, advances in global optimization permitted formulation of larger, industrially relevant problems with variable topology, nonlinear quality blending, and crude operations scheduling. This paper reviews the pooling problem by discussing modeling and problem formulation for every sub-class of the pooling problem, highlighting global optimization algorithms that were developed to unravel pooling problems, and describing the computational studies performed on benchmark problems. Our objective is for instance the long-standing symbiosis between the economic challenge of optimally combining feed stocks into products and therefore the mathematical field of worldwide optimization.

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