On a mixed 0-1 separable non-linear approach for water irrigation scheduling


Abstract

We present a mixed 0-1 separable nonlinear approach for the optimization of the water resources management for agriculture irrigation usage in a daily basis. It provides a dynamic planning of the daily irrigation scheduling for a given land area by considering the irrigation network topography, water flow technical conditions and logistics operation constraints for optimizing the usage of the stored water in a reservoir. We present a mixed 0-1 separable nonlinear program and a solution procedure that iteratively solves a mixed 0-1 linear approximation of the model. We are not aware of any previous attempt to solve large-scale mixed 0-1 separable nonlinear programs of this kind. Some computational experience on a large-scale real-life problem is reported.

Keywords: water resource scheduling, agriculture irrigation, mixed 0-1 separable nonlinear program.

Problem description

- Each sector head has a given elevation and water pressure.
- Daily Irrigation (Five periods of 4 h).
- Minimal water pressure required in each node.
- Maximum velocity in the pipe segments.

The water pressure at a given hydrant is a function of the pressure at the sector head, the elevation difference between the sector head and the given hydrant, and the head loss.

Computing the friction factor $f_M$

The mixed 0-1 program (1)-(6) has an additional difficulty. The friction factor can be calculated by using the Colebrook-White equation (see e.g., [3, 4]), it has the following expression,

\[ \frac{1}{f_M} = \frac{1}{f_{sw}} + \frac{1}{f_{sw}} \approx \frac{1}{f_{sw}} \left( \frac{1}{1 + \frac{5 \cdot 10^{-5} \cdot \frac{d}{H}}{R_e}} \right), \]

where $\gamma$ is a constant related to the roughness of the immediate upstream pipe segment of hydrant $i$, $\nu$ is the water kinematic viscosity, and $V$ gives the water flow velocity.

The computation of $f_M$ will be iteratively performed at each outer iteration of the algorithm for a given water discharge through the hydrants. Considering (7) as a nonlinear equation in $f_M$, we make use of the Newton-Raphson procedure for obtaining its roots. This procedure starts with a value of $f_M$ obtained by using only the first term of the right-hand side of the Colebrook-White formula, and approaches the root by steps which are proportional to the quotient of the equation (7) and its derivative. (An explicit calculation of the friction factor in a set of special pipes is presented in [6]).

Computational Experince

The approach presented was used to solve a real-life problem presented by ‘Comunidad de Regantes, Riegos del Guadiaro’ system optimization, which is located in Eastern Spain.

- Irrigation area of 2188 Ha distributed in 20 pipe sectors.
- 3211 nodes (2055 hydrant nodes).
- The pipe length and the pipe diameter vary from 0 to 691 m and from 66 to 800 mm.
- Reservoir Capacity of 13 Hm³

Conclusions

In this paper we have presented a new model and an algorithm for irrigation scheduling by using a pilot case a real-life problem from a land area of Eastern Spain. The model is a very large mixed 0-1 separable nonlinear program. It is solved by iteratively optimizing a mixed 0-1 linear program approximation, and usually takes a very short elapsed time. The computational results lead us to consider, in a future work, the use of the proposed approach in an extension of the irrigation network.

Bibliography


