Comparison of Model Predictive Control and Linear Quadratic Regulator when applied to a single reach.

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1 Introduction

Several studies can be found in literature where control strategies are used to control reaches or irrigation canals, such as PI controllers, heuristic controllers, predictive controllers and optimal controllers [1]. The dynamics of such a reach can be described by the Saint-Venant equations: two nonlinear partial differential equations. Because of computational reasons these controllers do not work directly with these equations but use approximating models, e.g. models based on the linearized Saint-Venant equations. The Linear Quadratic Regulator (LQR) is an example of a control strategy working with such a linear model. [2, 3, 4] show that this technique can be used for set-point control. However as we will show, this controller cannot be used at the same time for flood control.

2 Model predictive control

This problem does not exist with Model Predictive Control (MPC). MPC is a control strategy originating from the process industry and is used in various applications going from chemicals and food processing to automotive and aerospace applications. Just as for LQR, one can find many studies in literature where MPC is used for set-point control [5, 6, 7]. However these works do not focus on flood control. In previous work [8] we have been using a very simplified conceptual model which models the water levels of a river system only at a very limited number of points for set-point control in combination with flood control. In this work we use a linear version of the Saint-Venant equations with a very fine spatial discretization for designing and implementing the control strategies.

3 Results

We have compared the control performance of LQR and MPC for three different test cases: set-point control, disturbance rejection and flood control. For each of these cases MPC outperforms LQR. For the case of set-point control, MPC reaches new set-points after a change in the reference signal earlier than LQR. When a disturbance is present, the resulting steady state offset is much smaller when MPC is used, and for large disturbances MPC succeeds in preventing the river from flooding by temporaly creating extra buffer capacity. This is not the case for LQR.

In future work we will test MPC on river systems with multiple reaches, gates and junctions. Furthermore, an estimator will be added to the current control scheme in order to estimate the discharges and water levels of a river system from only a small number of measurements.

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References

[1] P. Malaterre, D. Rogers, and J. Schuurmans, "Classification of canal control algorithms," *Journal of Irrigation and Drainage Engineering*, vol. 124, pp. 3–10, January/February 1998.

[2] A. Clemmens and J. Schuurmans, "Simple optimal downstream feedback canal controllers: Theory," *Journal of Irrigation and Drainage Engineering*, vol. 130, pp. 26–34, February 2004.

[3] P. Malaterre, "Pilote: Linear quadratic optimal controller for irrigation canals," *Journal of Irrigation and Drainage Engineering*, vol. 124, pp. 187–194, July/August 1998.

[4] O. Balogun, M. Hubbard, and J. DeVries, "Automatic control of canal flow using linear quadratic regulator theory," *Journal of Hydraulic Engineering*, vol. 114, pp. 75–102, January 1988.

[5] P. van Overloop, *Model Predictive Control of Open Water Systems*. PhD thesis, Technische Universiteit Delft, 2006.

[6] M. Xu, P. van Overloop, and N. van de Giesen, "On the study of control effectiveness and computational efficiency of reduced saint-venant model in model predictive control of open channel flow," *Advances in Water Resources*, vol. 34, pp. 282–290, 2011.

[7] B. Wahlin and A. Clemmens, "Automatic downstream water-level feedback control of branching canal networks: theory," *Journal of Irrigation and Drainage Engineering*, vol. 132, no. 3, pp. 208–219, 2006.

[8] M. Breckpot, T. Barjas Blanco, and B. De Moor, "Flood control of rivers with nonlinear model predictive control and moving horizon estimation," in *49th IEEE Conference on Desicion and Control*, pp. 6107–6112, 2010.