Smarter Stormwater Networks:

Unlike the current state-of-the art stormwater solutions, these “smarter” stormwater networks retrofitted with sensors and actuators have the ability monitor the state of the network in near real-time and dynamically adapt their response to individual storm events.

The ability to control the response of stormwater assets during a storm event enables us to enhance the performance of the existing infrastructure by maximizing its utility (i.e. increasing the amount of stormwater capture).

By choosing to withhold water in an asset (A in the above figure) by anticipating an incoming storm event, storage utilization in the asset can be maximized (B in the above figure) to achieve network scale benefits.

Control of Stormwater Networks:

Decision to either capture or release water is relatively straightforward when controlling one or two assets. But controlling stormwater networks (often with hundreds of assets) to achieve complex network wide objectives is not as straightforward. As the decision process has to account for the network topology and the cascading impacts of spatially distributed assets. In this work, we propose a completely automated framework based on bayesian optimization for identifying an optimal control strategy for controlling stormwater networks.

Bayesian Optimization:

Bayesian optimization identifies an optimal solution by interacting with the system and learning a surrogate objective function. This approach uses gaussian process (GP) for modelling the surrogate.

Rather than just predicting an estimate, GP learns to predict the uncertainty associated with these predicted estimates. These uncertainty estimates are then leveraged by the bayesian optimizer using an acquisition function to effectively learn the surrogate. Algorithm for bayesian optimization is presented below.

Controlling a Stormwater Asset

10th Iteration

In this scenario, we control a single stormwater basin to maintain its outflows for an incoming storm event below an exceedance threshold by regulating the valve at its outlet between 0.0 (closed) to 1.0 (completely open). Bayesian optimization is used to identify the optimal valve position that achieves this objective.

Bayesian optimization identifies the optimal valve position by simulating the response of the stormwater network to various valve positions. Initially, optimizer has a high degree of uncertainty about the surrogate and as the number of simulations increase this uncertainty reduces (illustrated in the above figure). Optimal solution for this scenario identified from the above surrogate function is presented below.

Confidence Interval

Surrogate Objective Function

Acquisition

Storm events experienced by the stormwater networks are often highly stochastic. This introduces a high degree of uncertainty that has to be quantified to identify a control decision that is reasonably robust to this stochasticity. Bayesian optimization quantifies this uncertainty (i.e. input uncertainty) by simulating an ensemble of possible storm events.

Conclusison:

Bayesian optimization is a completely automated data driven approach for identifying a control strategy that achieves the desired response from the stormwater network. This approach can be used to quantify the uncertainty associated with the storm events and identify robust control strategies. The ability of the bayesian optimization to identify an optimal control strategy that satisfies the requirement is dependent on the formulation of the objective. Though GP are very useful for quantifying the uncertainty, they inherit the limitations of the non-parametric approaches.

Acquisition function identifies the best valve opening to simulate to reduce the uncertainty in surrogate.

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