Using Adaptive Direct Policy Search Method to Adapt to Sea-Level Rise

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\section*{Introduction}

- **Direct policy search (DPS)** is an approach for identifying optimal policies for managing a system by expressing decisions as a function of variables characterizing the system’s current state and exogenous forces acting on it.
- We use DPS to develop adaptive rules for upgrading dike systems for flood risk management in response to observed sea-level rise and storm surge event.
- Policies are optimized based on average performance over a large ensemble of future states of the world (SOW).
- This presents an opportunity to improve the method by incorporating learning over time: we add the predicted future values of state variables to the policy definition.
- This is done in a way that effectively reweights the SOWs according to our beliefs about their relative likelihoods.

\section*{Methods}

- This new algorithm incorporates learning into the standard DPS method.
- The result is a hybrid approach where today’s deep uncertainties, treated using ensemble analysis, are characterized probabilistically as the system evolves and we update our beliefs about what type of SOW is being experienced over time.

\section*{Results}

- We simultaneously minimize two objectives: the discounted costs of (i) dike upgrades and (ii) expected residual economic damage.
- The identified Pareto frontier of efficient policies shows improvement in the two objectives over a large ensemble of plausible SOWs.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
\textbf{Hyper-volume} & \textbf{Low Water Level} & \textbf{Medium Water Level} & \textbf{High Water Level} \\
\hline
\textbf{Standard DPS} & 115917.86 & 120396.80 & 871764.42 \\
\textbf{Adaptive DPS} & 219994.17 & 175580.74 & 1174700.17 \\
\hline
\textbf{Improvement (\%)} & 89.78 & 45.84 & 34.75 \\
\hline
\end{tabular}
\caption{Comparison of hypervolume for low/medium/high water level SOWs}
\end{table}

\section*{Conclusion}

- We examine the performance over three grouped SOWs based on the levels of sea level rise (i.e., low, medium, high).
- The Pareto frontiers turn out to have dominant solutions over the ones generated by the standard DPS in every level the sea level rise is stratified into.
- The adaptive DPS can save 1 million euros of cost while achieving the same level of residual risk on average.
- This better reflects the real world where we learn more each year about factors like sea level rise.
- In future, we plan to apply this new method to a realistic process-based model of coastal flood risk to evaluate its potential to improve the policy design.