Classification and uptake of reservoir operation optimization methods

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- Reservoir operation optimization can offer great efficiency gains for water supply systems as shown in numerous scientific studies [1]. However there is currently a limited uptake of these methods in practice.
- Our hypothesis is that the emphasis on mathematical algorithm features rather than applicability to the real world limits the practitioner's ability to select appropriate algorithms.
- We review available algorithms, propose a problem driven classification system to enable easy selection and are interviewing water managers and decision makers to validate our hypothesis.

Motivation

Continued **expansion** of hard infrastructure for water supply is becoming increasingly **unfeasible** [1]. We are ever aware of its environmental impact and the complexity involved in predicting situations in the distant future. One alternative is the re-purposing or networking of the existing supplies to improve reliability. Operation optimization can **maximize the efficiency** of these changes.

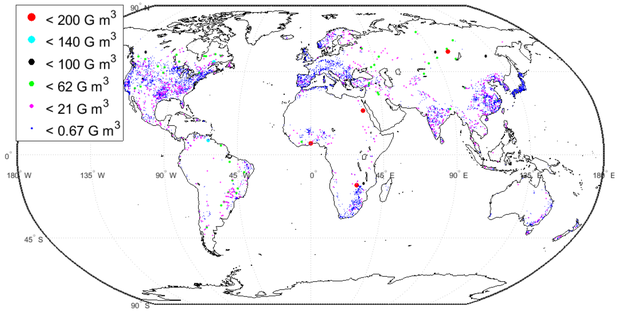


Figure 1: World map of lakes and reservoirs used as water resources [2] (with capacity >0.1 G m^3)

We may increasingly see **revision of supply operations** by water managers as issues like environmental restrictions or changing rainfall variability become prevalent, particularly in countries with extensive **existing supply infrastructure** (Figures 1 and 2)

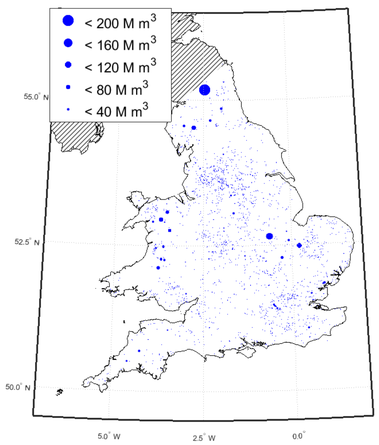


Figure 2: UK large reservoirs (>0.015 M m^3) by capacity, data from the dam registers of England and Wales.

Classification of optimization methods

A range of mathematical **optimization algorithms** and techniques have been tested in research. Current reviews focus on mathematical algorithm features which may not make sense if the context of optimization is not known by water managers and decision makers.

We propose a **classification** (Figure 6) of reservoir optimization algorithms driven by context and problem characteristics. This will make a system which is **easier to navigate** since these properties are more tangible and understandable to water managers or decision makers.

We have identified three distinct optimization contexts in which water management problems can be framed:

1. Release plan solving (RPS) is the optimization of a sequence of controlled releases given deterministic inflows, resulting in an optimal release plan (Figure 3).

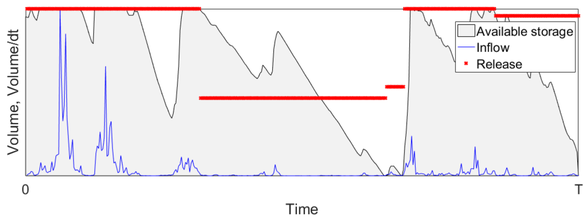


Figure 3: A release plan; optimal releases over a deterministic time-series of inflows, T. Note all variables have been normalized.

2. Offline policies are functions, which return a release given the current state (Figure 4).

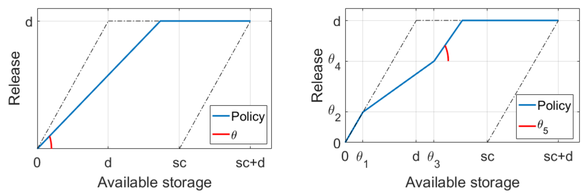
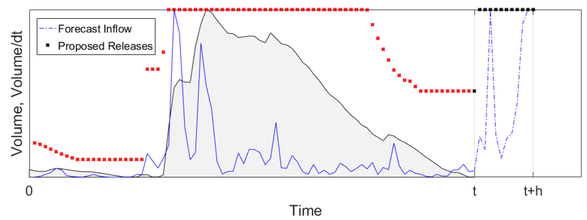


Figure 4: Offline policy; a release conditional on, in this example, available storage, demand, d, parameters, θ and storage capacity, sc.

3. Real-time policies use RPS on a short sequence of forecasted inflows with a penalization function to account for future beyond the release plan (Figure 5). The policy returns the first release in this plan.

Figure 5 (right): Real-time policy; over a forecast horizon, h. Note all variables have been normalized.



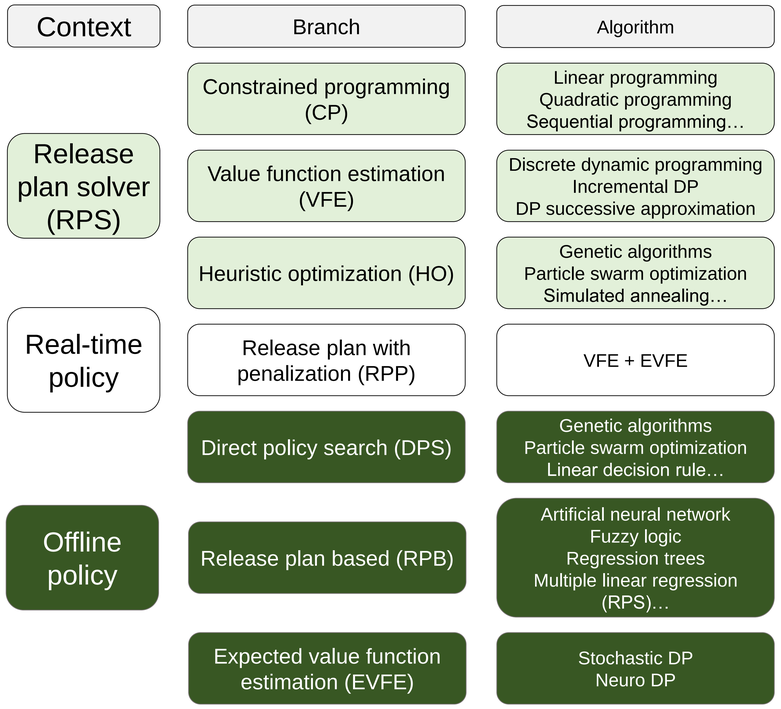


Figure 6: The novel classification system proposed (non-exhaustive algorithm list).

There is no unique branch suitable for each context. This choice will be determined by a range of selection pressures, including:

- **Multiple objectives**
- **Non-linear processes**
- **Time non-separable objectives**
- **Optimization duration**

The suitability of branches to various selection pressures is summarized (Table 1).

Branch	Refined and converged algorithms	Multiple objectives (typically >3)	Non-linearity	Time non-separable objective	Long inflow time-series	Linear scaling with time-series length	Multiple reservoirs (typically >3)	Stochastic flow regime with long memory	Suitable for penalization function	Suitable for real-time solver
CP	Y	N	M	M	M	N	Y	Y	N/A	?
VFE	Y	N	Y	N	Y	Y	M	Y	N/A	Y
HO	M	Y	Y	Y	N	N	Y	Y	N/A	?
RPB-CP	M	N	N	M	M	N	Y	Y	?	N/A
RPB-VFE	M	N	Y	N	Y	Y	M	Y	?	N/A
DPS	N	Y	Y	Y	Y	Y	M	Y	?	N/A
EVFE	Y	N	Y	N	N/A	N/A	N	N	Y	N/A

Table 1: A summary of branches and their suitability to problem qualities where: Y means suitable, M means somewhat suitable, N means not suitable and ? means currently undemonstrated in literature.

Current Work

We are currently **interviewing water managers and decision makers** in the UK. We aim to assess the present state of reservoir operation in practice and determine if additional support beyond the classification system is required to improve uptake.

Acknowledgements

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References

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