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BAYESIAN MULTI-OBJECTIVE OPTIMIZATION WITH NOISY EVALUATIONS

1. CONTEXT
• Multi-objective optimization of the parameters of a planning strategy for the multi-year planning of the electricity distribution grid [DUT15]
• A stochastic black box provides noisy evaluation results of the objective functions $f_1, ..., f_k$ defined on a discrete search domain $X \subseteq \mathbb{R}^d$
• Previous $n$ evaluations at $X = (X_1, ..., X_n)$ assumed:
  * $Z_i = f_i(X_i) + \epsilon_i$ for each $i \in [n]$
  * $\epsilon_i, j$ are zero-mean random variables

2. OBJECTIVE
Estimate the Pareto-optimal solutions (or Pareto set $\Gamma$) of the problem:
$$x^* = \arg\max_{x \in X} f_1(x), ..., f_k(x)$$
Defined as:
$$\Gamma = \{x \in X : \exists x' \in X \text{ such that } f(x') < f(x)\}$$
where $\Gamma$ stands for the Pareto domination rule:
$$x \prec y \iff \left\{ \begin{array}{c} y_1, y_2, y_3 \text{ are non-dominated points} \\ y_1 \text{ is only dominated by } y_2 \\ y_2 \text{ is only dominated by } y_3 \\ y_3 \text{ is dominated by all other points} \end{array} \right. $$

3. BAYESIAN OPTIMIZATION
• Define a probabilistic model for each $f$ conditional on previous observations
• Use a sampling criterion to select new evaluation points

PROPOSED APPROACH
• Replace the multi-objective problem by the minimization of a single augmented Tchebycheff function [KNO06]:
$$\begin{align*}
\tilde{f}(x) &= \max_{i \in [k]} \omega_i f_i(x) + \rho \sum_{i \in [k]} \omega_i f_i(x) , \\
\sum_{i \in [k]} \omega_i &= 1, \rho > 0
\end{align*}$$
• At each iteration, generate random weights $\omega_i$ and apply this function to the $n$ previous observations:
$$Z_i = \max_{i \in [k]} \omega_i Z_i, \quad i = 1, ..., n$$
• Assume a homoscedastic Gaussian noise model and fit to $Z = (Z_1, ..., Z_n)$ a Gaussian Process model $\xi_n$ with parameters estimated by maximum likelihood
• We use the Knowledge Gradient (KG) criterion [FRA09] to select new point $X_{n+1}$ based on previous observations.

4. NUMERICAL EXPERIMENTS
• Compare use of batches of 1, 4 or 10 evaluations
• Compare use of batches of 1 (black), 4 (blue) or 10 (magenta) evaluations.

5. OPEN QUESTIONS
• ‘Ideal’ batch of evaluations?
• Performance comparison of the proposed approach to other methods in the literature?

REFERENCES

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