Sample Efficient Preference-based Optimization for Industrial Automation

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Abstract

Industrial automation by robots employs rule-based and reinforcement learning-based approaches; however, these methods require experts to redesign rules and evaluation functions when the environment or task changes or personalization becomes necessary. A preference-based approach that obtains evaluation functions and policies from queries about relative preference relations is attractive since it has the potential to eliminate such adjustments. Therefore, this dissertation focuses on such a preference-based approach. For industrial automation purposes, it is necessary to overcome the following difficulties: (1) non-experts often give incorrect responses to hard-to-judgment queries, and (2) most industries need to perform optimization with a small number of queries. To this end, in this dissertation, preference-based Bayesian optimization is employed to overcome these problems. Bayesian optimization generates queries while considering the trade-off between exploration and exploitation, thus enabling optimization with few queries. Also, to increase sample efficiency while dealing with the uncertainty of non-experts' answers, a query synthesis mechanism was proposed that allows them to skip answering queries under certain conditions and synthesize new queries from the skipped ones. The proposed approach was applied to tasks in the food service and waste management industries, which have the above two difficulties but different characteristics. First, for tasks in the food service industry, where personalization is required, we proposed a method to estimate the preferred food arrangement while considering physical consistency and rules from chefs. Then, for tasks in the management industry, which require dealing with various waste environments, we proposed a framework to optimize the parameters of the controller of garbage cranes. The results of simulation experiments and non-expert subject experiments performed on both tasks indicate the effectiveness of the proposed approach.