Efficient Interpretation of Large-Scale Real Data by Static Inverse Optimization

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Abstract — Behavior of humans and animals seems to have some rationality as a result of evolution. We propose a new methodology based on a rationality hypothesis for interpreting real world data. The interpretation is carried out by "inverse optimization." Inverse optimization is classified into static inverse optimization and dynamic inverse optimization. In this paper we focus on the former, which estimates a criterion function under which given data become optimal subject to given constraints and provides interpretation of large-scale real data.

We have proposed a neural network approach to static inverse optimization for estimating a quadratic criterion function corresponding to given data. A crucial idea is a proposal of neural network architecture representing both optimization and inverse optimization. Taking advantage of this duality, static inverse optimization problems can be solved by learning of neural networks. This idea alone, however, is not sufficient to solve inverse optimization. To overcome various difficulties, we have also proposed such algorithms as generation of constraints from given data, guaranteeing positive semi-definiteness of resulting criterion functions, generating simple and understandable criterion functions, and interpretation of non-Pareto optimal data. Although it can solve static inverse optimization problems and interpret real data, it still has a difficulty in interpreting large-scale real data due to computational complexity in generating constraints.

Generation of constraints requires computation of a convex-hull from given data. Although algorithms for calculating a convex-hull from a set of points in 2-D and 3-D have been proposed, they cannot be applicable to data in higher dimensions. To overcome this difficulty we propose an efficient method for generating constraints by divide-and-conquer. The proposed algorithm randomly divides large-scale data into several subsets, calculates Pareto optimal data in each subset, and calculates Pareto optimal data from the union of these Pareto optimal data. It can be proved that resulting Pareto optimal data are the same as those obtained directly from the original data. Computational cost is much smaller than that by a naive algorithm without divide-and-conquer.

To evaluate the effectiveness of the proposed algorithm, simulation experiments are carried out. We use real data of about 4,000 houses with 4 attributes, i.e. rent, commuting time, area of housing and years after construction. These data are obtained from tenants along Yamanote and Soubu-Chou lines in Tokyo. In this case, computational cost for obtaining the constraints reduces down to 10^{-7} times due to divide-and-conquer. The resulting criterion functions show the followings. (1) The longer the commuting time is, the larger the corresponding monetary value is. (2) The longer the commuting time is, the larger the monetary value of area of housing is. (3) The longer the commuting time is, the smaller the monetary value of years after construction is. These results well accord with data and our intuition.

Keywords: inverse optimization, neural network, learning, divide-and-conquer.