Abstract

論 文 の 内 容 の 要 旨

論文題目　Approximate Submodularity in Machine Learning
（機械学習における近似的劣モジュラ性）

氏　名　藤井　海斗

Submodularity is a property that represents diminishing returns and appears ubiquitously in machine learning problems. By utilizing submodularity, many efficient algorithms with theoretical guarantees have been developed. However, there are still many problems that cannot be dealt with under the framework of submodularity. One promising approach to these problems is to extract properties close to submodularity, which we call approximate submodularity, and devise algorithms by extending existing results on submodularity. In this dissertation, we propose two new notions of approximate submodularity: adaptive submodularity ratio and approximate submodularity for local search. By utilizing these two notions, we develop efficient algorithms for various machine learning problems.

The first notion we propose is the adaptive submodularity ratio, which represents approximate submodularity in adaptive optimization. We are often confronted with a decision-making problem where the objective function is uncertain. In adaptive optimization, a decision-maker aims at gradually constructing a solution by repeating small decisions while gathering information on the objective function. To make a better solution, it is vital to perform adaptively, that is, to change the next decision according to the information obtained so far. It is known that if the objective function satisfies adaptive submodularity, which is an adaptive analog of submodularity, an adaptive greedy algorithm is guaranteed to work well. However, there are still many adaptive optimization problems that do not have adaptive submodularity. To analyze these problems, we propose the notion of adaptive submodularity ratio, which measures how close the objective function is to adaptive submodularity and provide a theoretical guarantee for the adaptive greedy algorithm in terms of this notion. We also apply a

similar approach to the batch-mode setting of adaptive optimization, in which the decision-maker obtains information all at once after making multiple decisions. By extending the framework of adaptive submodularity ratio to the batch-mode setting, we provide theoretical guarantees for greedy-based algorithms.

The second notion we propose is approximate submodularity for local search. Local search is a well- known algorithm design technique for combinatorial optimization problems. Local search algorithms start with an initial solution and gradually increase the objective value by repeatedly moving the solution to a nearby point. First, we analyze local search algorithms for feature selection. Feature selection is the problem of selecting a significant subset out of a large number of features and a vital component of sparse regression, compressed sensing, and structure learning of graphical models. By utilizing approximate submodularity for local search, we analyze and accelerate local search algorithms for feature selection. Next, we tackle dictionary selection, which can be regarded as a two-stage version of feature selection. A dictionary is a collection of patterns that make up signals in the real world. Dictionary selection is the problem of learning a dictionary suitable for the given dataset by selecting a subset of the union of ready-made dictionaries. Based on approximate submodularity for local search, we develop an efficient greedy algorithm Replacement OMP with theoretical guarantees.