論 文 の 内 容 の 要 旨

論文題目　Asymptotically Optimal Multi-armed Bandit Algorithms Aimed at Online Contents Selection（オンラインコンテンツ選択のための漸近最適な多腕バンディットアルゴリズム）

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A multi-armed bandit problem is a crystallized instance of a sequential decision-making problem in an uncertain environment. The history of this problem at least goes back to the 1930s, and it has recently attracted attention in the machine learning community. This problem involves conceptual entities called arms, and a forecaster who tries to identify good arms from bad ones. At each round, the forecaster draws one of the K arms and receives a corresponding reward. The aim of the forecaster is to maximize the cumulative reward over rounds, which is achieved by running an algorithm that balances the exploration (acquisition of information) and the exploitation (utilization of information). The notion of strong consistency introduced by Lai and Robbins (1985) defines the optimal balance between the exploration and the exploitation for a certain class of robust algorithms. At the beginning of the 2000s, an algorithm based on the upper confidence bound was established. Around that time, people found that many problems in web systems that involve uncertainty are related to the multi-armed bandit problem.

In each round of the multi-armed bandit problem, the algorithm selects an arm and receives a reward. In other words, the three core notions in the multi-armed bandit problem are (i) the sequential selection of arms, (ii) the criterion of selection (i.e., single arm selecting), and (iii) the reward feedback. However, these three notions are usually violated in practical applications: there are gaps between the multi-armed bandit framework and practical problems in web systems to which we would like to apply it.

In this thesis, we first review the history and the state-of-the-art framework of the multi-armed bandit. Then, we propose three extensions to the multi-armed bandit problem, which are intended to fill these gaps. Namely, (i) we propose the lock-up bandit problem, which models technical restrictions on the sequential selection of arms.

(ii) Motivated by the problem of <u>online</u> advertisement placement, we study a multiple-play version of the multi-armed bandit problem. We propose an extension of the Thompson sampling algorithm and show its effectiveness both theoretically and empirically. Moreover, (iii) motivated by problems arising in the information retrieval domain, we study the <u>dueling</u> bandit problem, a variant of the multi-armed bandit problem in which only the result of a pairwise comparison is available. A family of algorithms based on the likelihood function is proposed, and their effectiveness is verified.

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