Improved Algorithm on Online Clustering of Bandits

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Motivation – Reinforcement Learning

AlphaGo, AlphaStar
Motivation -- Multi-armed Bandits

• A special case of Reinforcement Learning
Multi-armed Bandits

• There are \( L \) arms
  • Each arm \( a \) has an unknown reward distribution with unknown mean \( \alpha(a) \)
  • The best arm is \( a^* = \arg\max_a \alpha(a) \)

• At each time \( t \)
  • The learning agent selects an arm \( a_t \)
  • Observes the reward \( X_{a_t,t} \)
Multi-armed Bandits (Continued)

• The objective is to minimize the regret in $T$ rounds

$$R(T) = T \cdot \alpha(a^*) - \mathbb{E} \left[ \sum_{t=1}^{T} \alpha(a_t) \right]$$

• Balance the trade-off between exploitation and exploration
  • Exploitation: select arms that yield good results so far
  • Exploration: select arms that have not been tried much before
Contextual Multi-armed Bandits

• Contexts
  • User profiles, search key words
  • Important for search, recommendations

• Usually suppose each arm $a$ has a feature representation $x_{a,t} \in \mathbb{R}^d$
  • Contexts could change over time

• The reward mean is $\alpha_t(a) = \theta^T x_{a,t}$
  • for some fixed but unknown weight vector $\theta$
Online Clustering of Bandits

• Drawbacks of simple contextual bandits
  • They assume the weight vector $\theta$ is the same for all users

• Online clustering of bandits
  • Users with strong ties (like friendship) usually have similar interests
  • Assume
    • Users within the same cluster have the same $\theta$
    • Users of different clusters have weight gap $||\theta_i - \theta_j|| \geq \gamma$
  • Find clustering adaptively as well as recommending
Existing Problems

• They assume the user distribution is uniform

• If generalizing the algorithm to arbitrary distribution over users
  • Their algorithm is much inefficient
  • The regret will depend on the minimal user frequency
  • \( R(T) = O\left(d \sqrt{mT \ln T} + \frac{1}{p_{\min} r^2 \lambda_\chi^3} \ln T\right) \)
Our Work – SCLUB (set-based clustering of bandits)

- Generalize the setting to allow arbitrary distribution over users

- Split a user out of the current cluster if we finds inconsistency

- Merge two good clusters together
Results

• Regret

\[ R(T) = O \left( d \sqrt{mT} \ln T + \left( \frac{1}{\gamma_p^2} + \frac{n_u}{\gamma^2 \lambda_x^3} \right) \ln T \right) \]

• compared to \( R(T) = O \left( d \sqrt{mT} \ln T + \frac{1}{p_{\min} \gamma^2 \lambda_x^3} \ln T \right) \)
Experiments – Synthetic

• 1000 users, 10 clusters, randomly generated weight vectors, $d = 20$
• (a) uniform distribution over users
• (b) arbitrary distribution over clusters
• (c) arbitrary distribution over users

• ---Ours ---CLUB ---LinUCB-One ---LinUCB-Ind
Experiments – Real Datasets

• 1000 users, $d = 20$
• (a)(c) uniform distribution over users
• (b)(d) arbitrary distribution over users

• ---Ours ---CLUB ---LinUCB-One ---LinUCB-Ind
Future Work

• Asymmetric relationships between users
  • Recommendations for low-frequency users can use information (or feedback) from high-frequency users, but not vice versa
  • Nested clusters

• Use the same idea to improve the collaborative filtering bandits

• Generalize the collaborative filtering bandits to the setting of changing item set
Thanks!
&
Questions?