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Approximation Algorithms for Envy-Free Cake Division with Connected Pieces

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Abstract: Cake cutting is a classic model for studying fair division of a heterogeneous, divisible resource among agents with individual preferences. Addressing cake division under a typical requirement that each agent must receive a connected piece of the cake, we develop approximation algorithms for finding envy-free (fair) cake divisions. In particular, this work improves the state-of-the-art additive approximation bound for this fundamental problem. Our results hold for general cake division instances in which the agents' valuations satisfy basic assumptions and are normalized (to have value 1 for the cake). Furthermore, the developed algorithms execute in polynomial time under the standard Robertson-Webb query model.

Prior work has shown that one can efficiently compute a cake division (with connected pieces) in which the additive envy of any agent is at most $1/3$. An efficient algorithm is also known for finding connected cake divisions that are (almost) $1/2$-multiplicatively envy-free. Improving the additive approximation guarantee and maintaining the multiplicative one, we develop a polynomial-time algorithm that computes a connected cake division that is both $(1/4 + o(1))$-additively envy-free and $(1/2 - o(1))$-multiplicatively envy-free. Our algorithm is based on the ideas of interval growing and envy-cycle elimination.

In addition, we study cake division instances in which the number of distinct valuations across the agents is parametrically bounded. We show that such cake division instances admit a fully polynomial-time approximation scheme for connected envy-free cake division.

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