Algorithmic Cost Allocation Games

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Abstract: Our work deals with the cost allocation problem, which arises when several participants share the costs of building or using a common infrastructure. We attempt to answer the question: What is a fair cost allocation among participants? By combining cooperative game theory and state-of-the-art algorithms from linear and integer programming, our work not only defines fair cost allocations but also calculates them numerically for large real-world applications.

First, in the theoretical part, we present and discuss several game-theoretical concepts. These concepts consider not only different aspects of fairness but also practical requirements, which, to the best of our knowledge, have not been considered in previous research. In addition, this part also investigates the computational complexity by calculating allocations based on the game-theoretical concepts. If the cost function is submodular, then one can find them in oracle-polynomial time. However, the problem is NP-hard in general. The biggest challenge is that there is exponential number of possible coalitions. To tackle this issue, we construct a constraint generation approach as well as primal and dual heuristics for its separation problem.

In the second part, based on the framework in the first part, we consider the ticket pricing problem of the Dutch IC railway network. The current distance tariff results in a situation that some passengers in the central region of the country pay over 25% more than the costs they incur, and these excess payments subsidize operations elsewhere. In this case, it is obvious that the cost allocation is unfair. Using our method, we suggest new ticket prices which can reflect costs better and reduce the overpayments to less than 1.68%.

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