Vehicle Sharing System Operational Optimization

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We study one way vehicle sharing systems (where users can pick-up and return a vehicle in different places). This new type of transportation system has many advantages but even if advertising promotes an image of flexibility and price accessibility, in reality customers are often unable to find a vehicle at the original station (which may be considered as an infinite price), or worse a parking spot at destination.

To tackle this problem and improve the overall utility, in bike sharing systems, vehicles relocation is used to reduce the saturation of stations and hence maximize the vehicle utilization. It is a specific Vehicle Routing Problem to which several research papers are devoted. Contrarily to bikes, in car sharing systems such as Autolib' (Paris) or Car2Go (Vancouver, ULM…), vehicle relocation seems inappropriate for its congestion and environmental costs (bigger vehicles). Current studies tend to focus on the best sizing of the system, in extremely simplified models. For instance George and Xia [2] is based on a closed form (product) formula for infinite station capacity. Gast and Fricker [1] proposed a Mean Field Approximation considering completely uniform cities. In particular, neither of these studies take into account "tide" effects due to periodic traffic flows between residential, working, commercial and leisure areas of the city.

In this study we focus on self regulating systems. Assuming that demand is elastic, we study how price policies may influence the efficiency of the system. Questions are first raised in terms of optimization models whose solutions are computed for each given city individually. More formally: for a given family of policies, how to find the "best" one in the family, given precise temporal stochastic demand forecast on a fixed set of parking stations? Two types of price setting policies are considered. Dynamic policies allow prices to be constantly recomputed in real time and to depend on all informations available on the current state of the system. Static policies allow prices to depend only on the trip chosen and/or the period of the day or the week. Dynamic policies lead to better theoretical solutions, but often frighten potential customers, so might or not be "optimal" once marketing costs are considered.

Computational complexity is a major issue when optimizing over policies, especially over dynamic ones. We first propose a Model based on Markov Decision Process which is used as a basis for simulation (that is comparison of policies) and optimization (that is searching for a good policy). Optimal dynamic policies are intractable (for descriptive reasons even on cities with few stations). Dynamic policies should thus be confined to descriptively tractable classes, before entering any optimization process. Static policies are also intractable for but less severe reasons (typically NP-hardness). Approximate strategies and models, such as fluid limit are thus investigated and compared experimentally on artificial cities of various size and characteristics.

References

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