RIde-hail VEhicle Routing (RIVER) as a congestion game

Kenan Zhang

Archak Mittal

Shadi Djavadian

Richard Twumasi-Boakye

Yu (Marco) Nie

STRC conference paper 2022 **May 10, 2022**

STRC | **22nd Swiss Transport Research Conference**
Monte Verità / Ascona, May 18-20, 2022

RIde-hail VEhicle Routing (RIVER) as a congestion game

Kenan Zhang
IfA
ETH Zürich
CH-8096 Zurich
kenzhang@control.ee.ethz.ch

Archak Mittal
Robotics and Mobility Research
Ford Motor Company

Shadi Djavadian
Robotics and Mobility Research
Ford Motor Company

Richard Twumasi-Boakye
Robotics and Mobility Research
Ford Motor Company

Yu (Marco) Nie
Northwestern University

May 10, 2022

Abstract

The RIde-hail VEhilce Routing (RIVER) problem describes how drivers in a ride-hail market form a dynamic routing strategy according to the expected reward in each zone of the market. We model this decision-making problem as a Markov decision process (MDP), and view the drivers as playing an MDP routing game, with "congestion" induced by competitive matching in a zone. We define a Wardrop equilibrium for the MDP routing game, and then prove it exists and can be obtained by solving a fixed-point problem. We further show a system optimum can be achieved if drivers make individual routing decisions according to a cooperative reward rather than the personal reward. In other words, the proposed cooperative strategy "decentralizes" the system optimal solution in the MDP routing game. The results from numerical experiments, including a case study of Chicago, indicate the service mode plays a critical role in shaping system performance. While e-hail enjoys a higher fleet utilization rate than street-hail thanks to its more advanced matching technology, it may lead to a more uneven spatial distribution of vacant vehicle supply. As expected, cooperative routing improves system performance in terms of both total reward and equal distribution of supply. Yet, its benefit is much stronger in e-hail than in street-hail, especially when the supply is overly abundant. We also find, when a local demand surge occurs, the cooperative rewards rise in sync, similar to surge pricing. Interestingly, the impact of the price surge spreads broadly in space, propagating far beyond the epicenter of the event.

Keywords

ride-hail vehicle routing; Markov decision process; congestion game; Wardrop equilibrium