An Agent-Based Modeling Approach to Predicting the Demand of Connected Autonomous Vehicles

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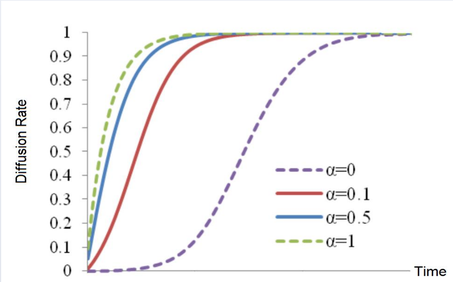
Introduction

- Connected Autonomous Vehicles (CAVs) will soon revolutionize transportation, but there is insufficient research on the demand for CAVs.
- How quickly will the population adopt CAVs?
- Inter-personal communication is essential to understanding how an innovation spreads through a social system.
- Choice modeling has been the prevailing method for forecasting CAV demand.
- Choice models fail to capture the effects that one individual's adoption may have on other individuals within his/her social network.

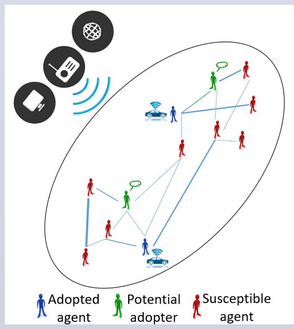


Diffusion Rate at Various Levels of Social Influence (Source: Namatame et al., 2009)

- $\alpha = 0$ represent innovation adoption patter when only personal preference is considered while $\alpha = 1$ shows the pattern when only social impact is in place.
- A promising alternative: Bridging Theory of Diffusion of Innovations and Agent-Based Modeling (ABM).
- Different from previous methods because agents are allowed to be heterogeneous and intercommunicate.

Methodology

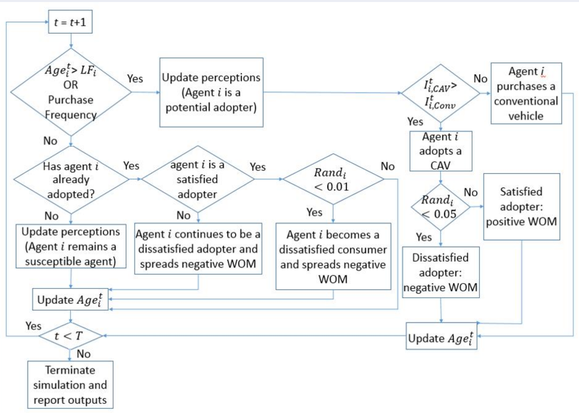
- Adopt or reject innovations: individuals have functional and psychological resistances (barriers) and incentives that promote/discourage adoption.
- Individuals also possess communication channels with other individuals that influence the decision to adopt an innovation.
- Agents who are connected to adopters are susceptible to adopt.
- Agents who are currently considering purchasing a vehicle are potential adopters of CAVs.
- Agents are influenced by their neighbors as well as external media like radio, television, and internet.
- Adopters may also spread negative word-of-mouth.



Visualization of Framework for Modeling Vehicle Adoption

Simulation Algorithm

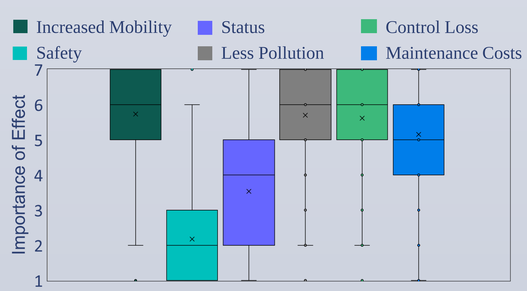
- Agents purchase vehicles based on either the age of their current vehicle or their personal purchasing behaviors.
- Agents then consider whether to buy a CAV or a conventional vehicle based on the perceived barriers and incentives of each alternative.
- If adopting a CAV, there is a chance that the agent will be dissatisfied, leading to negative word-of-mouth.
- Agents continue to spread positive or negative word-of-mouth to other agents in their network.



Agent-Based Simulation Algorithm

Data

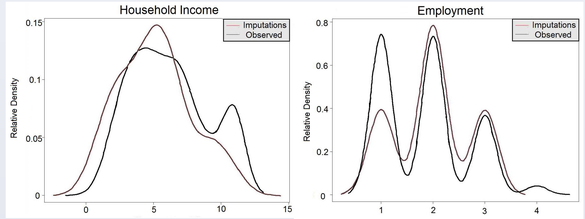
- Data was gathered from a survey distributed to the University of Memphis employees. The data was used to generate the synthetic population and network.
- 327 complete responses were gathered (13.3% response)
- The survey collected information on 8 distinct attributes, including socioeconomic characteristics, social behavior, personality, and perceived barriers to adoption.
- Social connections reported far more reliable than advertisement or dealerships which validates our fundamental assumption.
- Work and non-work connections have comparable importance when purchasing a car.
- Mobility and reduction in pollution considered important.
- Lost feeling of control more critical than safety concerns.



Importance of Effects of Owning a CAV

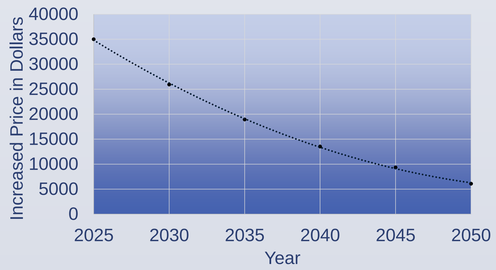
Data Cont'd

- Missing entries in survey: multivariate normal imputation.
- Multivariate normal imputation (MNI) assumes that the distribution of the dataset, including missing and observed entries, is multivariate normal.
- Although this is a crude assumption, the literature suggests strong evidence that MNI performs as well as other more complicated models, even if nominal or ordinal data exists.
- Comparing density of imputed and observed data shows acceptable quality of imputation.



Observed and Imputed Values of Employment and Household Income

- From the literature, we forecast that CAV technology will add roughly $35,000 to the price of a vehicle in 2025.
- As the price drops over time, agents who did not buy CAVs due to the increased prices will re-evaluate their decision.



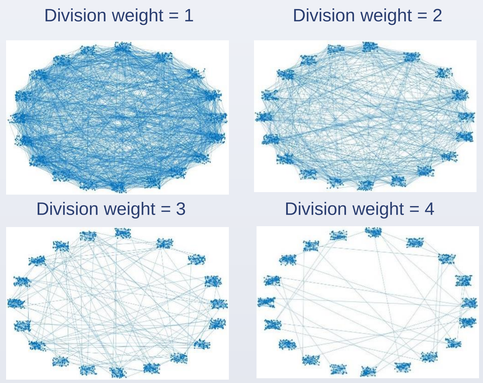
Forecast of Additional Price of CAV Technology Over Time

Synthetic Population and Network

- A synthetic population is generated by combining microdata samples with aggregate data about the true population.
- The Iterative Proportional Updating algorithm is used to generate the synthetic population.
- Synthetic network: agents are connected to each other based on the *homophily* principle, indicating that agents having similar attributes are more likely to have a connection.
- An 8-dimensional space is defined based on age, gender, race, employment type, income, disability status, telework habit, and college/division.
- A two-step selection algorithm is developed to connect agents based on mutual distance.
- The network exhibits a "small-world" effect, meaning that each agent can be connected to any other agent in the network through a small number of links.

Synthetic Population and Network Cont'd

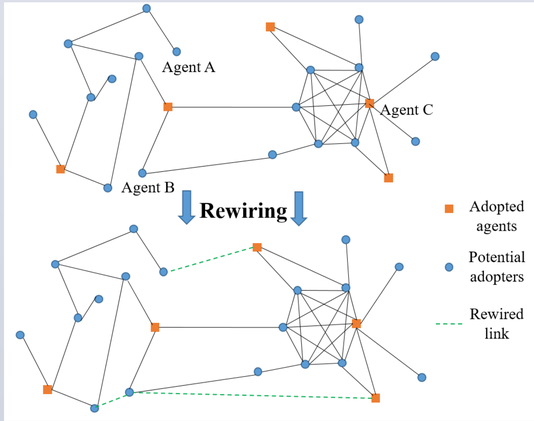
- The weight assigned to each attribute has a substantial impact on the structure of the synthetic network.
- Higher weights lead to clustering around the weighted attribute.



Effect of Division Weight Factor on Network Structure

Ongoing Efforts and Future Research

- Current effort: implementing the Agent-Based simulation model.
- Social networks are not constant; they change over time for a variety of reasons.
- Our model assumes that the synthetic network does not change, but connections can be revised due to geographical proximity or socio-economic changes.
- Future studies will focus on changes in the synthetic network over time.



Effect of Network Topology on Adoption

Acknowledgements

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