Multi-agent Simulator for Personal Mobility Vehicle Sharing

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Abstract. For future transportation, boarding type personal mobilities are considered promising. On introducing such mobilities in community, sharing is more prospective than owing. In this paper, we aim at considering expected change of human behavior, including modal shift, by introducing such mobilities in society. In the hope of large scale demand prediction and optimal planning of both location and capacity of the personal mobility sharing stations, we have developed a prototype multi-agent simulator. Parameters of simulation are determined by sharing experiments in Mobility Robot Experimental Zone in Tsukuba using Toyota Winglet long type and conjoint analysis based on questionnaires. We obtained preliminary results for a realistic situation.

Keywords: Personal mobility · Sharing · Simulation · Mobility robot

1 Introduction

For future transportation, boarding type personal mobilities (simply called PMs hereafter) are considered promising. They include Toyota Winglet [1], Segway [2], and AIST micro mobility [3], and have many advantages as follows. They are environmentally friendly. Their energy consumption is low compared to other transportation means such as cars, buses, and trains. PMs do not emit carbon dioxide during operation. Furthermore, it is human friendly. Relatively slow speed helps avoiding serious accidents, which are often fatal to elderly people. PMs are well suited to the concept of compact cities [4,5], which is advocated to solve various problems such as environmental, energy, and safety problems, caused by urban mobility.

On introducing PMs in community, sharing is more prospective than owing. Sharing usually costs much lower than purchasing. Users need not maintain or repair. Moreover, necessary parking area is much smaller. It is especially effective for connecting purposes from home or office to train stations or bus stops. If PMs are introduced in town, human flow is changed and new behavior will emerge. Sharing systems of PMs, however, have not yet studied enough.

As for sharing of mobility, bicycle sharing has been studied [6–8], and is popular recently in big cities. Vélib in Paris, Barclays Cycle Hire in London,

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and Capital Bikeshare in Washington, D.C. are examples of many successful systems. There, bicycles are rented at sharing stations and can be returned to any convenient station among many in the city.

In this paper, we aim at considering expected change of human behavior, including modal shift, by introducing PM sharing in society. In the hope of large scale demand prediction and optimal planning of both location and capacity of PM stations, we have developed a prototype multi-agent simulator. The behavior of mobility decision is modeled by the nested logit model [9]. One difficulty in such simulation is that the accuracy of simulation is not clear. To make the assumption closer to real situations, we use actual data obtained by experiments in Mobility Robot Experimental Zone in Tsukuba [10]. Parameters of the simulation were decided by the sharing experiments using four units of Winglet long type and conjoint analysis based on questionnaires. Supposed scenario for simulation here is traveling behavior of employees of our institute (AIST) for business trip between AIST and the nearest train station. We conduct simulations and evaluate the effect of introducing the sharing system of PMs.

2 Personal Mobility Sharing Simulator

2.1 PM Sharing

PM sharing seems prospective, but to evaluate the future demand of PMs, we need some evaluation method. Among various possible methods, micro simulation based on multi-agent model is suited for small to medium scale simulation because of its flexibility in configuration for individual agents with different characteristics in walking speed, riding speed and mobility preference attributed by age, gender, and so on. Also, various behaviors due to the limited number of PMs and capacity of PM stations on renting and returning are treated naturally.

Similarly to bicycle sharing, we need to consider the case where PM station is full upon return. In that case, the user cannot return the PM immediately to the station, and needs to wait or return it to another nearby station. Also, there is a problem that PMs may be accumulated at some station due to biased usage.

PM sharing is different from bicycle sharing in the following aspects.

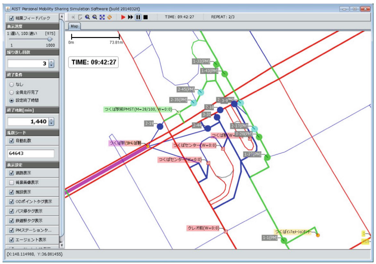
- Charging time is required. When the mobility is returned to a station, some charging time, depending on the riding distance or time of the previous user, is necessary before it is rented to a new user.
- Seamless PM riding between indoor and outdoor is possible. Sometimes this helps much for visiting shopping malls, museums, etc.
- PMs can be carried easily in other transportation means such as trains and cars. This usage will expand PMs' range of operation.
- Because information processing capability is equipped, assistance by IT infrastructure will be easy.

2.2 Simulator Overview

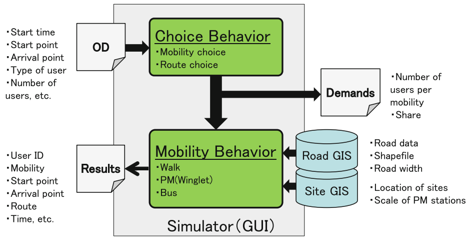
We have developed a prototype simulator for PM sharing. A snapshot and a configuration diagram of the simulator are shown in Fig. 1. A schematic diagram of the whole framework, including behavior and decision models, is shown in Fig. 2.

We adopt a simple behavior model. Each agent is generated at some designated time in the simulator, who has start and the goal points, and then decides its behavior stochastically by a decision model. If the agent chooses, e.g., a bus, it walks to the nearest bus stop, waits and gets on a bus, gets off the bus at the bus stop close to its goal points, and walks to the goal. The free flow speed for waking and riding PMs are given but actual speeds decrease depending on the ratio decided by the attributes of the agent and the density of pedestrians on the same segment of the roads.

As a decision model, we adopt a nested logit model. The utility function of each mobility is assumed to be a weighted sum of factors such as distance, estimated required time, estimated delay time, and preference of main transportation means. Each agent can make decision of transportation means when



(a) Snapshot



(b) Configuration diagram

Fig. 1. Prototype simulator.

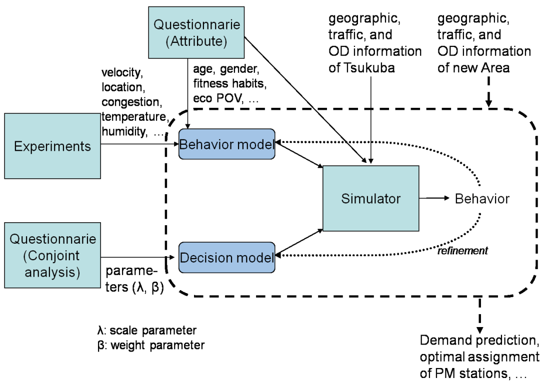


Fig. 2. Schematic diagram.

being generated, and, assug some digital aid, when receiving emptiness information on its heading PM station.

Parameters of the behavior model and the decision model for the simulator are decided by the experiments in Tsukuba and questionnaire. By feedback of such information, these models can be refined. Once a simulator with these models can be developed with geographic, traffic and OD information of Tsukuba, presumably, this can be applied to other places by providing such information of the areas, and simulation can be conducted for demand prediction or planning of optimal assignment of PM stations in both location and capacity.

2.3 Deciding Parameters

One difficulty in such simulation is that the accuracy is not clear. To make the assumption closer to real situations, we obtain actual data by small scale outdoor sharing experiments in Tsukuba Mobility Robot Experimental Zone using Toyota Winglet.

Tsukuba was approved in 2011 as Japan's first Mobility Robot Experimental Zone, which permits the boarding type robots to travel on public sidewalks with 3 m wide at the maximum speed of 10 km/h [10]. In Japan, riding such mobility on public sidewalks is generally prohibited and it is difficult to conduct experiments and obtain realistic data using PMs in other areas.

In the experiments, four units of Winglet were used. Winglet weighs 19.7 kg. It takes one hour for full charge from empty, and then one hour riding is possible for about 4 km. Fast charging in 15 min for 80 % is possible. It is in compact size compared to Segway, with ease of use, and can be much adapted in community especially in indoor environment.

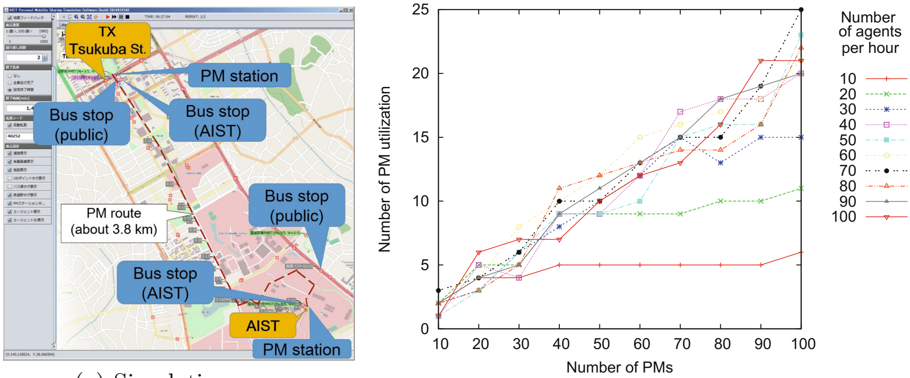
3 Simulation

3.1 Simulation Settings

Supposed scenario for simulation is traveling behavior of employees of our institute (AIST) on business trip; moving between AIST and the nearest train station is focused. The distance is about 3.8 km. The road network is given to the simulator as a shapefile. As transportation means, we assume PMs, walk and two types of buses, shuttle bus and public bus. In the simulation, we use actual timetables of buses and actual locations of bus stops. Two PM stations are assumed to be located near the start/goal points. These are shown in Fig. 3(a).

In the decision model, two buses are in a single nest. The weights for the utility function are decided through conjoint analysis based on questionnaires, which were conducted for 45 people after PM training course. In terms of the behavior model, actual experimental results were utilized in a way that free flow speed of PMs is changed depending on the actually obtained data for several road segments.

Under the above settings, simulations were conducted from 9:00 to 17:00 by changing the number of generated agents and PMs. When there is no available



(a) Simulation area

(b) Simulation result

Fig. 3. Simulation.

PMs at a station, the users wait for a fixed amount of time, called maximum wait time. After the time, users give up using PMs and choose another means (walk, in this case). The wait time actually affects the utility of PMs, but it is difficult to estimate it in advance. Therefore, we conduct simulation 10 times with feedback of the simulated wait time of PMs.

Main parameters of the behavior model are as follows. Free flow speeds of PMs and walkers are 6 km/h and 4 km/h, respectively. Maximum wait time for PM at station is 500 s. Getting on/off the PMs takes no time. Moreover, we use a fixed time (15 min) for charging. Here, we consider only the case where PM stations are large enough to contain as many PMs so that PMs can be returned at any station any time.

3.2 Simulation Results

The snapshot of Fig. 1(a) is from this simulation; the area shown is around Tsukuba Station. Lines indicate paths given by an input file and circles indicate moving agents. As an example of simulation results, the number of users using PMs is shown in Fig. 3(b). Each plot is the average of 5 simulation runs. Other parameters are: expected maximum delay time for buses is 20 min, route bus fare is 260 yen (as is), AIST bus is free, and emptiness notification ratio is 0. By changing these parameters, we can simulate various situations.

4 Conclusions

We have presented a prototype multi-agent simulator for personal mobility sharing. The simulator has the following features.

– The number of PMs are limited, and can be returned to any PM station within its limited capacity.

– Decision of users is modeled by the nested logit model.
– Various characteristic of the users, such as behavior and choice, can be configurable.

We conducted preliminary simulation and obtained results about share, the number of PM usage, and so on. We have lots of future work. We used plausible value for simulation parameters obtained from experiments and questionnaires, but still verifying the accuracy of simulation is not enough. In order to do this, calibration of the results should be considered. Also, we are planning to conduct sharing experiments in wider area with more PM stations and corresponding larger simulation. In that case we need to introduce other transportation means such as bicycles, trains, and private cars. Under the extensions, demands of the PMs can be evaluated under more realistic assumptions, and optimal planning of PM stations will be examined. Finally, different from just a transportation means, PMs are suitable for moving around for pleasure. Such activity should be incorporated as well.

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