F-MIRAI Project

Title: Mathematical approaches for mobility services in suburban areas

Industrial Partner: F-MIRAI at University of Tsukuba

Toyota will lead the way to the future of mobility, enriching lives worldwide with the safest and most responsible ways of moving people. In the near future, cars are expected to connect with people and communities and to perform in new roles as part of human social infrastructure. New domains of service such as AI, autonomous driving, robotics, and connected cars are becoming especially important. Toyota aims to reach the ultimate goal of sustainable mobility, creating a mobile future society full of smiles. Toyota and the University of Tsukuba have jointly established the R&D Center for Frontiers of MIRAI in Policy and Technology (F-MIRAI), which advances toward Society 5.0 through the development of infrastructure for future communities and the formation of industrial centers through long-term collaborative action.

Industrial mentor

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Background:

Rapid suburban sprawl in metropolitan areas in Japan has led to the rapid development of peripheral satellite cities. High-speed railway networks and motorways have contributed considerably to improving connections among established metropolitan areas and these new peripheral cities. Nevertheless, rapid population growth has led simultaneously to construction of suburban sprawls without any schematic road planning.

Consequently, key functions of cities for the daily life of residents, such as commerce, administration, and schools, have diffused to suburban areas on the basis of widening use of private cars. Such development is neither sustainable nor desirable as populations age and as energy conservation becomes increasingly important. In principle, a higher quality of life can be achieved if key city functions are aggregated in city centers around main railway stations. This aggregation necessitates the adoption of better and more efficient public transportation networks in conjunction with small devices used for personal mobility.

Mobility-as-a-Service (MaaS*) describes the integration of different transportation modes to achieve mobility solutions that are consumed as a service. Mobility innovation can be implemented fully or partially as MaaS and Smart Cities. Its principles are often designated as the following: C, Connected; A, Autonomous; S, Sharing; E, Electric (CASE). A wider range of demonstration programs and commercial services is being provided to improve transportation safety, efficiency, and convenience. In particular, “IoT vehicle information” is anticipated for application to widely various services because it aggregates various information related to local transportation in an immediate, remote, and wide-area manner. The benefits of using IoT vehicle information with AI to meet transportation challenges and support local economic growth are important.

* MaaS: integration of various forms of transport services into a single mobility service that is accessible on demand. To meet a customer’s request, a MaaS operator provides a diverse menu of transport options, be they public transport, ride-, car- or bike-sharing, taxi or car rental/lease, or some combination thereof. For the user, MaaS can offer added value through use of a single application to provide access to mobility, with a single payment channel instead of multiple ticketing and payment operations. For its users, MaaS is expected to be the best value proposition, helping users meet their mobility needs and solve the inconvenient aspects of individual journeys as well as the entire system of mobility services.

Source: MaaS Alliance, https://maas-alliance.eu/homepage/what-is-maas/

Project and Expectations

Many studies and demonstration experiments have elucidated MaaS as an implementation of CASE, particularly for metropolitan areas where other multiple transportation modes such as rails, metro, and buses are available. Nevertheless, other areas for which private cars constitute the dominant transportation mode have not been investigated thoroughly. Mobility services for non-metropolitan areas can differ from those for metropolitan areas because of differences in population density/distribution, transportation demand, and public transportation networks. As an example, Tsukuba city, a city with a population of 241,000 people, and located 60 km northeast of Tokyo, has a transportation system that is dependent on private cars. However, Tsukuba city was designed as a science city such that the University of Tsukuba, which also has a hospital, is positioned as the center of its urban function. Therefore, MaaS centered on the university can be a good example of a future transportation system in a non-metropolitan area. Furthermore, the scope includes mobility services supporting the regional transportation network.

This project will design MaaS for practical cases for the campus of University of Tsukuba through analyses of person-trips and other related datasets. The present major transportation modes around the university are private cars, buses, bicycles, and walks. The services accompanied with mobility around the campus are various, ranging from education, health care, and nursing care, to childcare.

Participants are expected to estimate the overall transportation demand to optimize those services through analyses of available datasets such as traveling bus probe data and personal mobile data in Tsukuba city and peripheral areas, and to build a mathematical model as a system-of-systems based on some of the following perspectives. All can be considered with automated vehicles.

- Traffic prediction and forecasting and dynamic traffic control with information provision.
- Minimizing global energy consumption for travel of people.
- Optimal allocation of mobility services in the regional transportation network

Although several approaches for such problems already exist, participants are expected to find completely new mathematical approaches, descriptors, formulations, solvers, visualizations, operation plans, etc. to accommodate and support our future society with highly sophisticated modes of mobility (See Ref. [10]). Additionally, investigating the energy expenditure and traffic flow of cars in terms of dynamical systems theory is possible by implementing mathematical models into automated vehicles in a miniature traffic course on a trial basis. (See video in Ref. [9].)

Requirements

We welcome applications from motivated team-players who have knowledge and practical skills related to one or more of the following.

- Mathematical statistics
- Optimization
- Graph theory
- Dynamical systems theory
- Machine/ Deep learning
- Operations research
- Programming language (Python, C, or MATLAB)

Recommended Reading and References

[1] Applied Mathematical Programming. http://web.mit.edu/15.053/www/AMP.htm

[2] Nonlinear Dynamics and Chaos. https://www.youtube.com/playlist?list=PLbN57C5Zdl6j_qJA-pARJnKsmROzPnO9V

[3] Toyota Motor Corporation. Toyota e-Palette Concept Opening Video. 2018. https://www.youtube.com/watch?v=-z09mlA2mLU

[4] Toyota Motor Corporation. Toyota e-Palette Concept Basic Function Video. 2018. https://www.youtube.com/watch?v=XmoPQuMlOYE

[5] OECD/International Transport Forum. Shared Mobility: Innovation for Liveable City. 2016. https://www.itf-oecd.org/itf-work-shared-mobility

[6] GRIPS-Sendai 2018. Toyota Group Final report: Data-Driven Models for Predictive Control of Toyota's e-Palette Mobility System. 2018. (For those who have decided to participate)

[7] g-RIPS Sendai 2019. Toyota Group Final report: Implementation of TOYOTA's e-Palette Mobility System to Develop Data-Driven Optimization of Transportation Networks. 2019. (For those who have decided to participate)

[8] Mathematical Challenges and Opportunities for Autonomous Vehicles Tutorials IPAM long program: http://www.ipam.ucla.edu/programs/workshops/mathematical-challenges-and-opportunities-for-autonomous-vehicles-tutorials/?tab=schedule

[9] Miniature traffic model by F-MIRAI in University of Tsukuba (in Japanese):
https://youtu.be/NvHfrb0K6Fo

[10] Modeling Public Transportation Networks with Queues
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3986717