Research Projects in the SMART FM IRG
(December 4, 2018)

1. Project Title: Dynamic Redistribution of Demand for Peak Hour Congestion Management

**MIT Faculty Advisor:** Patrick JAILLET and Daniela RUS  
**Mentor:** Dr. Supriyo GHOSH and Dr. Malika MEGHANI  
**Email Address:** supriyo@smart.mit.edu and malika@smart.mit.edu

**Overview:** This project provides a new perspective for congestion management in public transport network during peak commuting hours. To tackle the congestion delay caused by uneven distribution of commuters’ demand, we need to take a global view of the entire network-wide spatio-temporal demand while recommending individual routes to commuters. In this project, we aim to develop light weighted optimization tools to decide upon the best possible routes for commuters that minimizes the congestion delay in the entire city network by employing techniques from Machine Learning and Operation Research.

**Qualifications/Skills:** Algorithms, combinatorial optimization (optional) and coding skill in python (preferred) or Java/C++.

**Goals:** To learn demand patterns from historical real-world data and design fast heuristic or optimization methods for route recommendation.

**References:** NIL

2. Project Title: Rebalancing Dockless Bike Sharing Systems for Dynamic Matching of Supply and Demand

**MIT Faculty Advisor:** Patrick JAILLET  
**Mentor:** Dr. Supriyo GHOSH  
**Email Address:** supriyo@smart.mit.edu

**Overview:** Bike-sharing systems are widely adopted in major cities of the world. While many existing works proposed solutions to reposition the idle bikes from congested station to empty station using carrier vehicles, this resource matching problem between demand and supply of bikes is still challenging in case of dockless bike-sharing systems (mainly deployed in Asian cities). Our goal for this project is to design optimization models to find the routing (for carrier vehicles) and repositioning (how many bikes to pickup/drop-off) solution for the dockless bike-sharing systems. Our goal also includes reduction of carbon emission by the carrier vehicles while designing this solution.

**Qualifications/Skills:** Mathematical optimization and coding skill in python (preferred) or Java/C++.
Research Projects in the SMART FM IRG  
(December 4, 2018)

**Goals:** To learn the customer demand from historical data of three dockless bike-sharing operators. We also expect to design some initial optimization models for solving the bike repositioning problem during this period.

**References:** NIL

3. **Project Title:** SimMobility Freight - Freight Friendly Policies

**MIT Faculty Advisor:** Moshe BEN-AKIVA  
**Mentor:** Andre ROMANO ALHO  
**Email Address:** andre.romano@smart.mit.edu

**Overview:** Logistics and goods movement are essential parts of our economy and communities. Growth in commodity and freight vehicle movements is expected for the next decades, particularly due to the increased relevance of e-commerce. However, there are concerns over the externalities generated by freight vehicles (pollution, congestion due to poor parking practices, inefficient operations, etc.) and several policy and regulatory measures are often times put forward as potential solutions. Simultaneously, changes in the freight distribution system are taking place, with new modes and services being deployed. Lastly, being a complex system with conflicting interests between agents (buyers, receivers, shippers, carriers, etc.), adds to the challenge of evaluating impacts of system changes at a broad and specific level.

In SMART FM, we have been developing SimMobility Freight, a multi-scale agent-based simulation platform that can be used to evaluate policy and “what-if” scenarios. With a working prototype, we have been applying the platform to real-world policy cases. We aim to generate insights that to contribute towards a understanding better on how changes to the status quo result in changes across the freight distribution systems and on their interactions with passenger travel. Ultimately these insights will allow for freight friendly policies, in the sense of being appealing to freight parties as well as to the community and the environment.

**Qualifications/Skills:** Agent-based simulation, data/statistical analysis, (light) programming and or scripting knowledge (e.g. Python)
Research Projects in the SMART FM IRG
(December 4, 2018)

Goals:
Become familiar with agent-based models and their role in making policy evaluations.
- Configure and apply SimMobility Freight models to “what-if” scenarios as per requirements at time of internship.
- Critically analyse model outputs, generate reports and insights.
- Propose follow up research tracks.
- Present findings to an audience of fellow researchers.

References: https://its.mit.edu/simmobility-freight

4. Project Title: SimMobility Passenger - Autonomous Mobility-on-Demand

MIT Faculty Advisor: Moshe BEN-AKIVA
Mentor: Simon OH
Email Address: simon@smart.mit.edu

Overview: Today, new business model introduced by transportation networking companies have changed the way we view the urban mobility system. Technology and business trends involving big data, machine learning, electrification, connectivity, and autonomy are set to bring additional opportunities to increase accessibility and mobility in urban areas. Particularly, in Singapore, the Autonomous Mobility-on-Demand (AMOD) system emerges as one of the promising alternatives which has enormous potentials and is rapidly embracing new business models on the shared mobility, on-demand ride-hailing, seamless multimodality. Moreover, municipalities are looking for ways to include the autonomous mobility services within public transport to overcome the land-scarce urban environment where the desire for car-ownership has to be balanced against traffic congestion and overall journey time. The initial effort on implementing the autonomous mobility solution predates to the creation of the Committee on Autonomous Road Transport for Singapore (CARTS, 2014) that aims to provide guidance on the research development and deployment of autonomous mobility for Singapore.

Making the AMOD solution as an integrated part of the mobility system is known to reduce inequality, especially when increasing accessibility of travelers to public transit and impacting car-ownership behavior. Yet, for a successful integration, it is crucial to properly understand the implication of this new mobility service under the Singapore context for both demand and supply. To this aim, SimMobility was developed by SMART FM to simulate of the effects of a portfolio of technology, policy and investment options under alternative future scenarios. It features (1) detailed interactions between the agents of demand (travelers) and supply (facility and the transportation operations) and (2) multiscale evaluations in time and space, comprising three primary modules (Short-term, Mid-term, and Long-term) in which we consider different decision-making levels of an urban system.
Qualifications/Skills: Graph theory; Optimization techniques; Programming language (e.g. Python, R, Matlab); Data/statistical analysis;

Goals:
- Design and formulation of AMOD service (i.e. Routing and matching) within given operational constraints
- Implementation and testing of the formulated AMOD solutions
- Simulation study with SimMobility over different service and policy configurations.
- Turn simulation output into scientific knowledge

References: [http://its.mit.edu/research/simmobility_v1](http://its.mit.edu/research/simmobility_v1)

5. Project Title: Maximum Entropy Inverse Reinforcement Learning for Route Choice Prediction

MIT Faculty Advisor: Patrick JAILLET
Mentor: Ahn Tien MAI
Email Address: mai.tien@smart.mit.edu

Overview: The project concerns the prediction of routes that a traveller would take in a transportation network, given an origin and destination (OD) pair and transport mode (e.g., car, bike or public transport). We are interested in models that are able to assign a probability distribution over possible paths that the traveller would take. The resulting probability distribution of paths can be used to predict traffic flows, simulate road users’ path choices or assess travelers’ preferences regarding characteristics of different routes (e.g. travel time, travel cost, number of crossings). One of the main issues associated with the use of such models is that the set of all possible paths between an OD pair is typically not possible to enumerate.

We are interested in models based on Markov Decision Process (MDP) and can be used to infer/learn utility (or reward) functions of road users without the need for path generation. In the transportation modeling literature, such models are referred to Markovian route choice models, which are firstly introduced by Fosgerau et al. (2013). These route choice models, interestingly, share many similarities with maximum entropy inverse reinforcement learning (ME-IRL) models in the machine learning literature (Ziebart et al., 2008).

In this project, we aim at investigating further the use of ME-IRL models to predict route choice behavior. More precisely, most of the studies in the context are based on linear-in-parameters utility functions. Nevertheless, some recent studies show nonlinear utilities may lead in better prediction performance. So, one of the interesting directions is to use some deep neutral networks to model the utility functions. This could be also interesting to see whether the nested structure (Mai et al. 2015) would be useful to improve ME-IRL models.

Qualifications/Skills: Dynamic programing, deep learning, reinforcement learning, MATLAB or Python.
Research Projects in the SMART FM IRG
(December 4, 2018)

**Goals:** The main goal is to implement and evaluate the prediction performance of ME-IRL models with different choices of nonlinear utility functions resulted from deep neural networks. Another goal is to apply the proposed route choice models to real data sets collected in Singapore. We also aim at providing packages for the estimation/training of large-scale route choice models for other researchers and practitioners.

**References:**

6. **Project Title:** Competitive facility location under general random utility models

**MIT Faculty Advisor:** Patrick JAILLET  
**Mentor:** Ahn Tien MAI  
**Email Address:** mai.tien@smart.mit.edu

**Overview:** This project concerns the facility location problem in a competitive market, which has been receiving a growing attention in the last decade due to its appealing properties and applications. The problem concerns how to locate new facilities in a competitive market such that the captured demand of users is maximized, assuming that each individual chooses among all available facilities according to a random utility maximization model (i.e., discrete choice model). In this problem, two aspects are taken into account, namely, the demand of customers and the competitors in the market. For the latter, the firms that would like to locate new facilities have to compete for their market share.

We focus on a probabilistic approach which allows capturing the demand of customers by a probabilistic model, i.e., a model that can assign a probability distribution over available facilities. The random utility maximization is convenient to use in the context. Under this framework, a random utility is associated with each facility, and a customer is assumed to choose a facility by maximizing his/her utilities. This way of modeling customers’ behavior allows to compute the probability that a customer chooses a facility versus other facilities in the network. Thus, the facility location problem can be described as follows: How to locate facilities in a competitive market such that the expected market share captured by the new facilities is maximized (so the problem is also called as the “maximum capture” problem).
The main challenge lies in the fact that the objective function resulted from the demand model becomes highly nonlinear. Under the multinomial logit model (MNL), the objective function is convex, so one can use a global approach (e.g., outer approximation, Branch-and-Cut). However, it is well-known that the MNL has some limits and there are more flexible demand models that have been developed over the recent decades, i.e., mixed-MNL, nested logit and Multivariate Extreme Value (MEV) models. Nevertheless, the use of such models would result in nonlinear and non-convex optimization problems, which are indeed difficult to solve. Due to this issue, existing studies only focus on the MNL or mixed-MNL models.

In this project, we deal with the competitive facility location problem under general discrete choice models, including the MEV model and mixed MNL. These demand models are fully flexible in the sense that they can approximate any random utility models. As mentioned, the resulting problems are challenging as the corresponding objective functions are highly nonlinear and non-convex, so heuristics and/or local search approaches would be interesting to investigate.

**Qualifications/Skills:** Mixed-integer programming, demand modeling, MATLAB or Python.

**Goals:** We aim at studying the structure of the objective function under a general discrete choice model, i.e., the mixed-MNL or MEV models. The ultimate goal is to have an efficient algorithm that would be able to give good facility location solutions in reasonable computing time.

**References:**

7. **Project Title:** A New Solution Method for the Facility Location Problem under Random Utility Models

**MIT Faculty Advisor:** Patrick JAILLET  
**Mentor:** Ahn Tien MAI  
**Email Address:** mai.tien@smart.mit.edu

**Overview:** This project concerns the facility location problem in competitive market, which has been receiving a growing attention in the last decade due to its appealing properties and applications. The problem concerns how to locate new facilities in a competitive market such that the captured demand of users is maximized, assuming that each individual chooses among all available facilities according to a random utility
maximization model (i.e., discrete choice models). In this problem, two aspects are taken into account, namely, the demand of customers and the competitors in the market. For the latter, the companies that would like to locate new facilities have to compete for their market share.

We focus on a probabilistic approach which allows to capture the demand of customers by a probabilistic model, i.e., a model that can assign a probability distribution over the available facilities. The random utility maximization is convenient to use in the context. Under this framework, a random utility is associated with each facility, and a customer is assumed to choose a facility by maximizing his/her utilities. This way of modeling customers’ behavior allows us to compute the probability that a customer chooses a facility versus other facilities in the network. Thus, the facility location problem can be described as follows: How to locate facilities in a competitive market such that the expected market share captured by the new facilities is maximized (so the problem is also called as the “maximum capture” problem).

In this project, we focus on the maximum capture problems under the MNL and mixed-MNL models. Such problems have an advantage that the objective function is convex. Moreover, it can be expressed as a sum of convex functions. Benefitting from this fact, we aim at exploring this separable structure to design new solution algorithms that allow to efficiently solve instances of large number of locations and clients.

Qualifications/Skills: Mixed-integer programming, demand modeling, MATLAB or Python

Goals: The main goal is to have a new global algorithm for the maximum capture problem under the MNL and mixed-MNL models. The new algorithm should be able to perform well on large-scale instances and outperforms state-of-the-art approaches.

References:

8. **Project Title:** Rollout Algorithms for Decision-Making under Random Utility Models

**MIT Faculty Advisor:** Patrick JAILLET  
**Mentor:** Ahn Tien MAI  
**Email Address:** mai.tien@smart.mit.edu

**Overview:** We are interested in a class of data-driven optimization problems in which one needs to use a demand model to predict customers’ behavior. Then, this demand model can be integrated into an optimization model for decision-making. Such problems have been widely studied in revenue management and location analysis, e.g., assortment planning and facility location in competitive markets. The former refers to the problem of selecting a subset of items that maximizes the expected revenue, and the latter is the problem of seeking to locate new facilities in a competitive market such that the captured demand of users is maximized. For the both problems, a typical approach is to formulate the decision-making problem as a mixed-integer nonlinear programming model, in which the decision variables are often binary. Under some specific settings, one can formulate the problem as a mixed-integer linear program, which is convenient to be solved. In general, such problems are difficult to deal with due to the fact that the objective functions are often highly nonlinear and non-convex.

In this project, we explore a new way to solve the nonlinear binary optimization problems. More precisely, we view the decision-making problem as a sequential optimization problem whereby the decision variables are optimized one after the other. This approach is referred to rollout algorithms that are originated in dynamic programming. The rollout approach already have several applications in discrete optimization, e.g., stochastic scheduling, network optimization. We expect that this approach would be an efficient alternative to other existing approaches to deal with decision-making problems under random utility maximization models.

**Qualifications/Skills:** Dynamic programming, demand modeling, MATLAB or Python

**Goals:** The main goal is to develop a rollout algorithm to solve the choice-based optimization problems mentioned above (assortment planning and facility location under random utility models).

**References:**
Research Projects in the SMART FM IRG
(December 4, 2018)