RÉGION BOURGOGNE FRANCHE COMTÉ

UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ

école doctorale **sciences pour l'ingénieur et microtechniques** SPIM

Titre de la thèse/Thesis title: Multimodal Carpooling with flexible roles

Laboratoire d'accueil / Host Laboratory: FEMTO-ST/DISC

Spécialité du doctorat préparé/Speciality : Informatique/Computer Science

Mots-clefs / Keywords: extended N-DARP, combinatorial algorithm, multimodal itinerary, massive open data, real-time

Descriptif détaillé de la thèse / Job description

1. Research context:

Public transport concerns less than 8% of the population while 92% of this same population uses their individual vehicle. 4% of drivers share their vehicle. It is necessary to integrate the use of personal vehicles within a Global Public Transportation Offer (GPTO and GPTOiIV stands for GPTO integrating Individual Vehicles) if we want to decarbonize our environment.The massification of available public transport data, progress in Artificial Intelligence and Operational Research, and the integration of the individual vehicle into a GPTO, make possible the invention of a new mobility offer (Mobility as a Service = MaaS) for better decarbonization of our environment.

The aim of this project is to propose the first PoC (Proof of Concept) of multimodal carpooling integrated into a GPTOiIV. The first challenge is to formalize the theoretical problem corresponding to an optimized service for carpooling a heterogeneous fleet of vehicles connecting to a public transport offer. In a way, it is a question of proposing a solution to the problem of the first and last-mile, as well as the absence of classic public transport (without integrated carpooling). The second challenge is to propose an operational solution to this problem for a service extending over, or even exceeding, an extensive territory such as that of the Belfort-Montbéliard-Héricourt Urban Area, a new metropolitan area under dynamic construction. The third challenge is to propose a functionally validated PoC, and also validated on performance tests that will have to be invented because multimodal carpooling has never been either formalized or resolved, even in an approximate version.

With more details, the first challenge is to formalize this problem as an extended multi-objective N-DARP such as having to minimize the number of vehicles used, or even minimize the consumption of carbon energy, and also to maximize the pooling of Individuals Vehicles (IVs). The extension should allow a certain unification of the problems of the VRP, the TSP and also the DARP. This is characterized by a more complex transport supply, or demand, of the form src -> [via ->]* dst, flexible and expanded user roles (only Driver, mainly Driver, mainly Passenger and only Passenger), a parameterization of multimodality (M-max of intra-modal transhipment, P-max of inter-modality transhipment), and a parameterization of coherent uses such as that of dropping off and picking up your vehicle, such as that of taking into account the compensation for carpooling and pricing of the complementary Public Transport offer. The constraints considered are the satisfaction of requests, the time windows [h-, h+] of earliest departure, latest departure and earliest arrival, latest arrivals, as well as the variable capacity constraints of the fleet heterogeneous vehicles.

The second challenge is to find one or more operational algorithmic solutions to this multimodal carpooling problem. The complexity is NP-hard. There are neither functional test sets in the literature, nor dedicated benchmarking test sets.

We are considering a mixed combinatorial approach mixing Greedy approach, Bi-Level approach with one or more Cut&Price&Share dynamic programming sub-algorithms. A first step should make it possible to resolve the problem of N-intra-modal carpooling on a GPTO. A second step should make it possible to resolve the problem of multimodal itineraries of a GPTO integrating carpooling, first static, and then dynamic.

Then a third challenge, more a thesis perspective, is to combine all of this TRL-3 work into a TRL-7 service platform that will make it possible to deploy a multimodal carpooling service integrated into a GPTO.

The 2nd and 3rd challenges require that the problem of aggregating open and heterogeneous data be addressed. Sometimes static, and rarely dynamic, public transport data is increasingly accessible

via open data, particularly from the data.gouv.fr site. Academic work has until now only dealt with single-source and single-format data while the formats are usually multiple (GTFX, Netex, SIRI) and with non-standardized semantic interpretations.

Research objectives:

There are 3 main objectives for this project:

1) Model the multimodal carpooling problem while respecting the 2 stages: that of N-intra-modality, that of combining M-inter-modality and N-intra-modality

2) design and develop operational combinatorial algorithms and metrics for decarbonization and optimized pooling of individual vehicles, functionally validated, and experimentally evaluated

3) carrying out functional test and benchmarking games,

appendix 1) carrying out test tests showing the potential for solving unified applied problems of the VRP, TSP and DARP

appendix 2) a real experiment of a multimodal carpooling service GPTOiIV and its study.

The work is planned over three years:

• M0-M12: Formalization of the multi-constraint and multi-objective extended N-DARP problem which corresponds to the multimodal carpooling problem integrated into an GPTO. Aggregation of heterogeneous public transport data, those open (data.gouv.fr) and those of a static then dynamic carpooling offer

• M13-M24: development of the first approximate algorithms, carbon-free metrics, test sets for this problem.

• M25-M36: Functional validation and performance evaluation, PoC.

Références bibliographiques / Bibliography

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[3] PIGALLE Éléonore & AGUILERA Anne, 2021. « Covoitureurs des villes, covoitureurs des champs. Une analyse spatialisée du covoiturage en France », *in* Yoann Demoli (dir.), *Peut-on se passer de la voiture hors des centres urbains ? Colloque (UVSQ – Laboratoire Printemps, Guyancourt, 27 février 2020)*, Gif-sur-Yvette, MSH Paris-Saclay Éditions, p. 173-187. Mis en ligne le 02/06/2021. DOI : https://doi.org/10.52983/KEFA8892.

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Profil demandé / Applicant profile

Students with a master's degree in one of the following domains: computer science or operational research, or artificial intelligence, or related degree e.g. Electronic/Electrical engineering.

Expected skills:

- Knowledge of operational research or combinatorial algorithm, with a particular focus on TSP, VRP, DARP and software engineering.

- Knowledge of AI or big data is not mandatory but will be considered positively for the application.
- Good knowledge of mathematical modelling.
- Good programming skills (C/C++, Python), computer graphics (GPU).
- Excellent communication and writing skills in English.

Preferred selection criteria:
- Excellent academic results.
- Good interview.
- Good oral skills and the ability to articulate technical concepts clearly and concisely.
- English and French speaking and writing.

Personal characteristics:
- Motivated, enthusiastic, and proactive.
- Ability to lead and direct your own research while taking on board suggested guidance.
- Good relationship, open mind.

Financement : Region UBFC – Graduate School EIPHI

Dossier à envoyer pour le / Deadline: **June 17, 2024**
Début du contrat / Start: **Octobre 1st, 2024**
Salaire mensuel brut / Monthly gross salary: **1975€**

Direction de la thèse:/ **Thesis Supervisor**

MABED Hakim / hakim.mabed@femto-st.fr

Encadrement de la thèse : **co-directeur(s) et co-encadrant(s)**

CANALDA Philippe / Co-supervisor / philippe.canalda@femto-st.fr
CECE Gérard / Co-supervisor / gerard.cece@univ-fcomte.fr

Applicants are invited to submit their application to the PhD supervisors.
Application must contain the following documents:
- CV
- Cover letter
- At least 1 reference letter
- - Transcript of master 1 and 2
- - Research project and end-of-study reports, as well as presentation materials
- - Any article submitted and/or accepted and/or published