

Towards Multi-Modal Advance Journey Planner in a Co-Modal Framework

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Abstract

Traveler information systems play a significant role in most travelers' daily trips. These systems assist travelers in choosing the best routes to reach their destinations and possibly select suitable departure times and modes for their trips. We present an advanced traveler information system (ATIS) for public and private transportation, including vehicle sharing and pooling services. The ATIS uses an agent based architecture and multi-objective optimization to answer trip planning requests from multiple users in a co-modal setting, considering vehicle preferences and conflicting criteria. At each set of user's requests, the transportation network is represented by a co-modal graph that allows decomposing the trip planning problem into smaller tasks: the shortest routes between the network nodes are determined and then combined to obtain possible itineraries. Using multi-objective optimization, the set of user vehicle-route combinations is determined according to the user's preferences, and all possible route agents' coalitions are ranked. The ATIS is tested for the real case study of the Lille metropolitan area (Nord Pas de Calais, France).

Keywords — Advanced traveller information system, trip planning, public transport, private transport, co-modal transport, multi-agent systems, directed graphs, optimization

I. INTRODUCTION

A. Contribution

SHARED transportation services are emerging concepts. In multi-modal transportation users employ at least two different types of means of transport. Co-modality, instead, arises from the need to convey people on a single means of transport to reduce the impact on environment, costs, and accidents. Hence, co-modality refers to the optimal use of different transportation modes on their own or in combination, which ensures advantage of ridesharing (the sharing of vehicles by passengers). Information and communication technologies may support the development of advanced tools for passengers allowing the effective integration of transportation modalities. As a result, the field of

intelligent transportation systems and particularly of Advanced Traveler Information Systems (ATISs) is rapidly growing. An ATIS is formed as a system providing pre-trip and real time information on departures, routes, and modes of travel. However, the related literature in the field of passengers' co-modal transportation services is scarce, showing a need for ATISs supporting sustainability-oriented decisions.

This paper aims at filling this gap by a multi-agent ATIS for passengers' pre-trip planning considering co-modal itineraries with multiple preference criteria, taking into account of public and private transportation, and including vehicle sharing and pooling. Users request itineraries to the ATIS, with given (eventually different) origin and destination pairs and arrival/departure time windows, specifying their preferences by an ordered sequence of criteria. The ATIS matches requests with information in transportation operators' databases and chooses transportation means and routes. It provides the routes answering requests and optimizing travel time, travel cost, and gas emissions. To the best of the authors' knowledge, no ATIS for trip planning exists in the literature for trip planning both with private and public transport in a co-modal and multi-objective framework, i.e., with multiple users and preferences. Moreover, with respect to the previous works by the authors, we remark here that the paper enhances and extends three previous contributions. The ATIS architecture borrows the multi-agent systems paradigm for improving the vehicle/operator/route/users association, which is here determined in a stand-alone way without using external software but rather representing the transportation network by a co-modal graph. In addition, here we provide two improvements: First, we enhance the trip calculation defining route agents to represent the possible routes composing the itinerary solution path and employing an agent coalition mechanism to determine the best person-to-vehicle assignment for the concerned route using genetic optimization. Second, the user can express his preference among different transportation means and define a descending order of priority of multiple criteria (cost, time, and emissions in the case study). Finally, we remark that the paper is a deeply revised.

Here we detail the multi agent architecture, only by describing all the agents operations. Moreover, we enhance the case study by presenting a totally new urban scenario together with an extra-urban scenario revisited.

B. The Co-Modal Trip Planning Problem

The scope of the proposed ATIS is to satisfy user’s requests for itineraries by answering trip requests respecting preferences. To this aim, the ATIS employs the notion of co-modality: combining all possible means of public transport with private transportations services, i.e., using different modes, on their own or in combination to reach an effective and sustainable utilization of resources. To improve sustainability, the ATIS considers multiple operators to offer the same service for each transportation service. We assume that multiple users formulate simultaneously (or in a short time window) a set of requests. Hence, the ATIS determines feasible decompositions of each itinerary or route, i.e., sub routes, by recognizing similarities in order to associate different users to the same vehicle and transportation service (so as to satisfy the co modality requirements). For a given route or sub route, several transportation possibilities may exist with different vehicles, which may all be available for that route through the same time window. The problem is thus to choose the most effective route combination for a given user, taking into account his constraints and preferences in terms of preferred means of transport and conflicting criteria, while considering the co-modality requirements. We adopt an aggregative approach to obtain the most effective solution by a compromise between criteria (transport time, total cost, and total gas emissions). By means of a weighted sum function, the aggregation method reduces the number of conflicting criteria by judiciously choosing the weights combining them into a single optimization criterion so that two conflicting criteria cannot be improved or deteriorated at the same time.

We remark that the optimization criteria of co-modal transport systems are typically multiple and conflicting. They depend on the physical situation (geolocalization of transport means), on the topological configuration of the transportation network, as well as on technical capabilities, institutional capacities, financing support, and political decisions. In addition, passenger’s preferences usually imply a conflicting situation in order to reach low cost, high quality services, rapid itineraries, comfort, safety and security. Here we choose three classical criteria that are clearly conflicting: travel time, travel cost, and gas emissions. For example, in the carpooling mode, the driver can make a detour to pick up new passengers. This detour increases the transport time and decreases the transport cost. In fact, the total cost of the itinerary is

cheaper for each passenger because the total costs involved are shared. Exactly because of the complicated nature of the problem, and due to the presence of conflicting criteria, we propose a multi-criteria decision making ATIS.

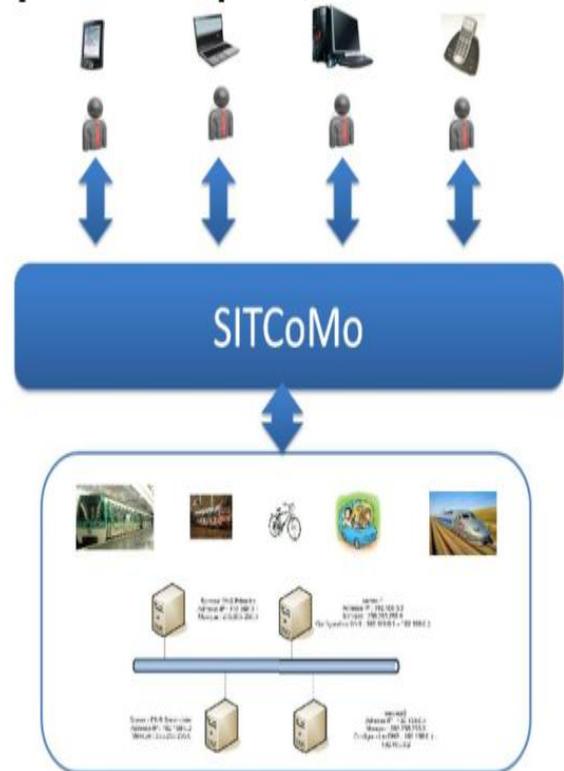


Figure: 1 Co-Modal Trip Planning

The main concern of our system is to combine all the existing transport services so as to satisfy the users by providing optimized co-modal itineraries and respecting their priorities criteria.

As shown in Fig.1, a transport user can use a medium of communication (e.g. laptop, PDA, smart phone) in order to express his demand and provide a departure and arrival points and the correspondent earlier and later schedules. In a short time interval, many transport users can formulate simultaneously a set of requests. So the system should find feasible decompositions in terms of independent sub itineraries called Routes recognizing similarities. For a given Route, we can have several possibilities with different vehicles which are available to ensure this Route through the same time window. All these identified Routes constitute our co-modal graph and we have to recognize the different possibilities of Routes Combinations to compose each itinerary demand. The problem is how to choose the most effective Route Combination to a given user, taking into account his constraints and preferences in terms of total cost, total travelling time and total greenhouse gas volume for example,

At a time t , our problem is defined by:

- N requests formulated through a short interval of time $\Delta \sim$ milliseconds. is the set of these requests.

In fact, the system catches simultaneously all travelers queries expressed through Δ^E .

- $I_k(d_k, a_k, W_k) \in I_t$ is an itinerary request formulated by a user k at a time t from a departure point d_k to an arrival point a_k through a time window $W_k = [td_k, ta_k]$; td_k and ta_k correspond respectively to the earliest (minimum departure time from d_k) and the latest (maximum arrival time to a_k) possible schedules with $t \leq td_k < ta_k$;

II. MULTI-AGENT SYSTEM ARCHITECTURE FOR A DISTRIBUTED CO-MODAL TRANSPORT SYSTEM

The agent computing paradigm is one of the powerful technologies for the development of distributed complex systems. The agent technology has found a growing success in different areas through the inherent distribution which allows for a natural decomposition of the system into multiple agents. These agents interact with each other to achieve a desired global goal. The transport domain is well suited for an agent-based approach since transport systems are usually geographically distributed in dynamic changing environments. Each agent is composed of states, different types of knowledge (environmental, social and personal), messages, behavior rules and a perception function. By using the behavior rule, the agent can modify its state according to current states, knowledge and received messages in order to reach the collective goal. A set of rules and behaviors can define a role. An agent can though have different roles. From a role to another, the agent changes its capabilities and behaviors. According to the problem described above, we propose a multi-agent system based on the coordination of several kinds of software. The architecture of the proposed multi-agent system is described below (Fig.2).

In our system, we consider K transport services and K_i transport operators associated to the transport service I ($i \in [1..K]$). we associate an agent to each transport service and an agent to each transport operator. A transport Service Agent ($TSA_i, 1 \leq i \leq K$) is responsible for a set of Transport Information Agent ($TIA_{i,j}, 1 \leq j \leq K_i$). Each $TSA_{i,j}$ is able to respond to an itinerary request $(x,y, W_{x,y})$ by a shortest path $RC_{x,y}^*$ that allows to go from x to y on a transport network of the operator j associated to the service i .

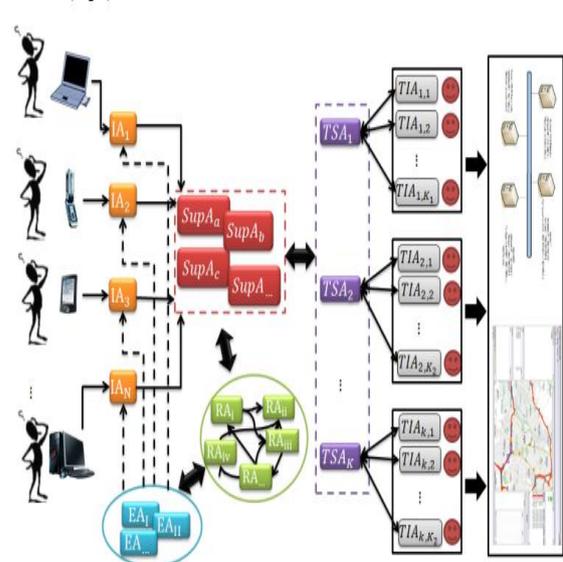


Figure: 2 Multi Agent System Architecture

For a global request $I_k(d_k, a_k, W_k) \in I_t$ an Interface Agent (IA) interacts with a system user allowing him to formulate his request choosing his preferences and constraints and displays at the end the correspondent results. When an IA handles a user request, it sends it to a SuperAgent (SupA). It is an agent with different important roles. Firstly, this agent asks the TSAs for a search domain and all the transport operators that will be involved in the itinerary research. We assume that the SupA has a global view of all the TSAs that define the environment. The SupA cooperates then with the set of TIAs identified by the TSAs and starts by constructing a co-modal graph. The SupA decomposes this complex graph into a special graph called "Transfer graph" and a co-modal approach is applied. After a first computing of the shortest paths in terms of time, the SupA generates all possible Route Combinations from simultaneous itinerary requests thanks to the Route Agents (RA). All the roles and the tasks executed by the SupA are detailed in the next sections.

The RA represents a generated chromosome scheme called VeSAR for an identified useful Route $I_k(d_k, a_k, W_k) \in I_t$ in order to assign concerned users to possible vehicles. As soon as each RA assigns persons to vehicles, updating the number of passengers in carpooling vehicles and the number of available vehicles of free use vehicle service, it computes all values criteria of each vehicle for each assignment. A multi-agent coalition is then created regrouping all RAs corresponding to a possible Route combination for a given itinerary. Therefore, we have as many coalitions as combinations knowing that an RA can belong to many different coalitions according to combinations overlapping. Coalitions appear and disappear dynamically according to requests receptions and responses.

The chromosome scheme generation and the assignment were explained in previous works. Then, the generated data is transferred to an Evaluator Agent (EA) who decides of the best Combinations thanks to its interaction with the autonomous RAs. The EA computes the best Combination Route for each itinerary demand and sends it to the correspondent IA.

III. TRIPPLANNER SYSTEM

Here, we first introduce several key terminologies. Then, we formally define the research problem of personalized trip planning. Finally, we give a detailed description of the framework of TRIP PLANNER system, which is composed of three major parts, namely, a dynamic POI network model, a route search component, and a route augmentation component.

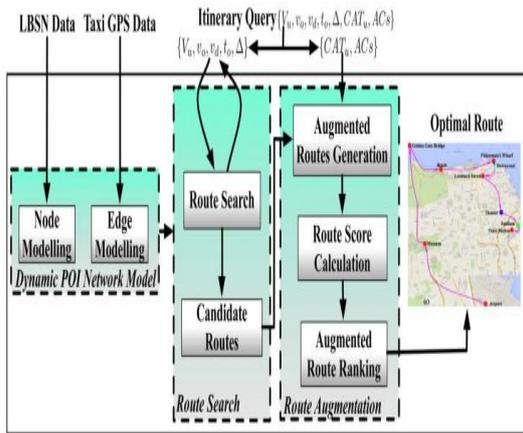


Figure 3. Framework of our proposed TRIP PLANNER.

As shown in Fig. 3, the proposed framework contains three components, i.e., the dynamic POI network model, the route search component, and the route augmentation component. While the dynamic POI network model is prebuilt and maintained offline, the route search and route augmentation components collaboratively answer users' trip queries in real time.

A. Dynamic POI Network Model: The key problem of POI network model construction is to separately extract attributes of POI nodes from the foursquare data set and information of the edges from the taxi GPS data set.

B. Route Search: Given user-specified venues to visit, the starting time, and the time budget, the route search component returns routes that traverse all the intended venues from the starting location to the destination. In particular, the returned routes with a time margin greater than a user-determined threshold become candidate input to the route augmentation component. However, users might list too many

venues to cover within the time constraint, or the planned visiting time does not agree with the operating hours of certain venues. If the TRIP PLANNER system detects any of those cases, it will interact with the user to manually modify the venue list.

C. Route Augmentation: This component aims to augment the candidate generated from the route search module with user-preferred venues inferred from the intended venue categories in the query, maximizing the route score under the given travel time budget. It first pulls together all of the venues that belong to user-preferred venue categories as candidate venues. Then for each candidate route, it tries to insert venues in the pool into it to generate an augmented route without breaking any constraint. In the end, TRIPPLANNER presents the augmented routes to the user, in an order sorted according to their scores in the augmented route ranking module.

Case Study: - Road Distance Guide Map from Bangalore to Ooty

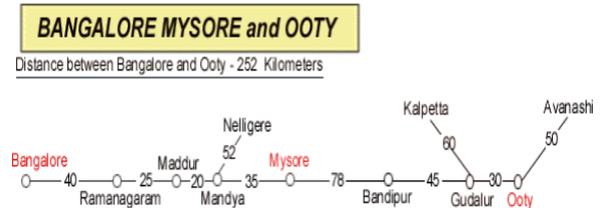


Figure 4 Distance Route Bangalore to Mysore

IV. RESULT

A. Screenshots

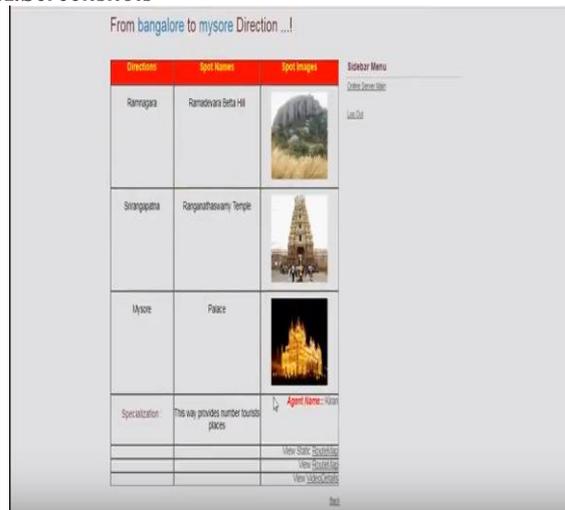


Figure 5. POI's Location in Bangalore to Mysore

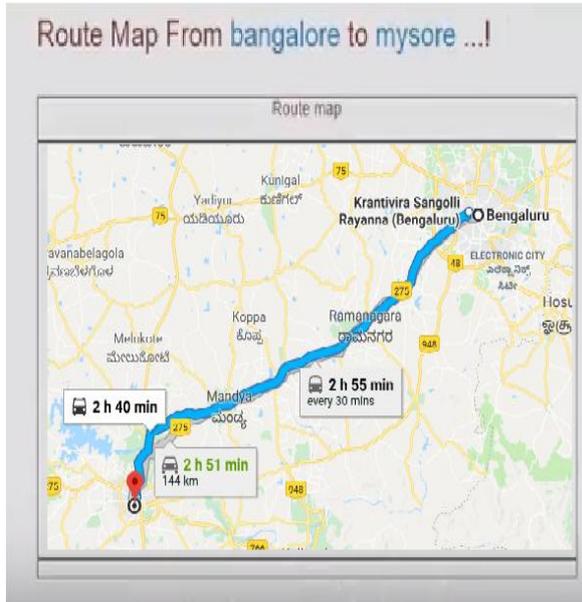


Figure 6. Travel time Between Bangalore to Mysore

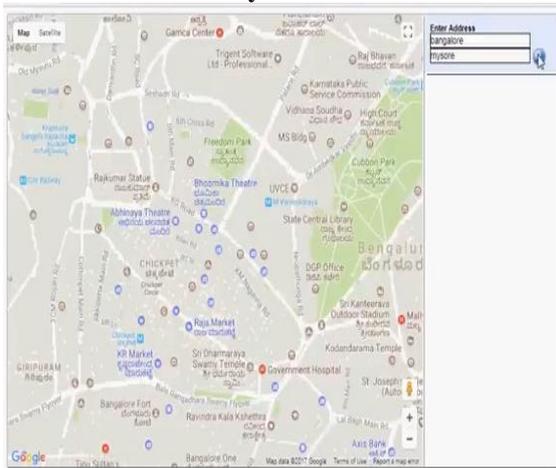


Figure 7. Search Distance between Bangalore to Mysore

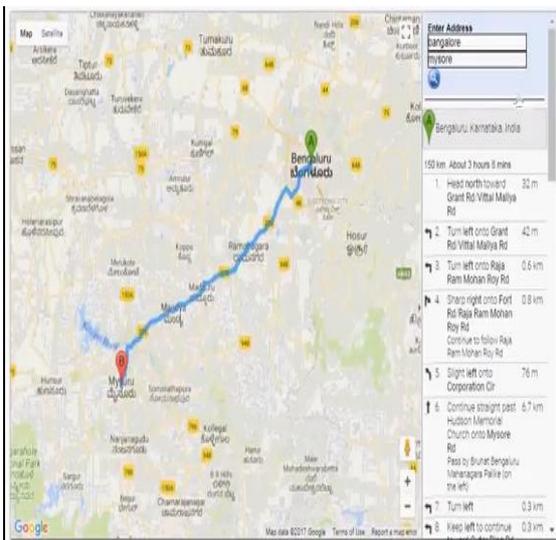


Figure 8 Routes and Transportations in Bangalore to Mysore

From bangalore to mysore		
Directions	Spot Names	Spot Images
Ramnagara	Ramadevara Betta Hill	
Srinagapetha	Ranganathaswamy Temple	
Mysore	Palace	
User Recommendations		
End User	Date	Interest
Rajesh	07/12/2017 15:45:28	Very good way for all tourist

Figure 9. User Recommendations

V. CONCLUSIONS

In this work, we proposed a distributed co-modal approach based on multi-agent system which aims to find an effective itinerary proposition to transport users including public transport, car sharing and carpooling. The system employs different optimization techniques. In fact, the developed Distributed Shortest Path Algorithm (DSRA) allows the system to simplify the resolution of shortest paths in term of time in a distributed system. Then, the system uses an evolutionary optimization approach in terms of total cost, time and gas emission volume taking into account user constraints and preferences. The employment of multi-agent system, the use of the co-modal and transfer graph and the rapid assignment process to a combinatory problem thanks to an evolutionary method, make our adopted approach very interesting. The alliance of multi-agent systems and different optimization techniques is very important because with agent based approaches we explore the ability to handle a large problem domain and a short time-scale of the domain while with the optimization techniques, we explore the ability to achieve system optimality or near optimality with a quality assurance. In future work, we intend to develop the evolutionary approach and the coalition of the RA generated by the SupA. We also aim to employ a genetic process generating more chromosome generations, in order to improve gradually generated solutions to find better solutions and to develop the protocol negotiation between the different RAs.

VIFUTURE ENHANCEMENT

Other extensions of this research include: conducting studies using multiple sensor sources (e.g. loop detectors, video cameras, taxi GPS data) and integrating the multi-agent IO approach; considering Bayesian techniques like Markov chain Monte Carlo methods for online learning through sampling (Tebaldi and West, 1998); and

designing more sophisticated online learning systems that incorporate time value of observations and deterioration rate of dual prices. For example, a new observation that shows dual price is 5 instead of 0 can have different meanings if the observation arrives 1 minute later versus 1 hour later. This temporal component needs to be studied. Other aspects of real applications also need to be considered: data can be noisy (e.g. perceived link capacity dual price for agents may differ) and may require stochastic assignment consideration (Ashok and Ben-Akiva, 2002), only fragments of actual paths may be available (e.g. transit fare smart card data), or travellers may choose to stay at home. Aggregation methods, while discussed in Chow and Djavadian (2015), can be further expanded upon in this generalized route inference setting.

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