Enhancing Launch Pads for Decision Making in Intelligent Mobility On-Demand* (Extended Abstract)

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Abstract—Interacting for shared mobility is a complex spatio-temporal task. Traditional approaches rely on the full disclosure of inherently private trip information to perform ride matching. Such a requirement however creates a rigid architecture with location privacy and service knowledge issues. Catering for these complexities, we extend previous work on an intuitive interface concept, launch pads, to address individual route choice by enhancing the visualization in a third dimension. This representation provides a client with a more detailed pick-up choice set. To examine the value of this enhancement, we implement a multi-agent simulation and observe a client agent’s responses to 3D launch pads visualized according to three different fare models. Results show that a client’s flexibility in space is dependent on the fare model chosen and by using the visualization they can increase their utility.

I. INTRODUCTION

Mobile applications for shared mobility, e.g., ad-hoc ride sharing [1], require intuitive human-computer interfaces for effective interaction and service usage. New communications technologies are inspiring the design of user services towards realization of a Mobility Internet [2]. Here novel location based services integrating advanced traveler information, are allowing users to search for and discover opportunities satisfying their intentions in space-time [3].

Existing user interfaces for ad-hoc ride sharing however are rigid. They rely on the full and a priori disclosure of trip information from persons for ride matching [4]. Whilst operations research describes client compromises in time using a stretch factor, e.g., [5], little research has sought to make matching intuitive, and consequently human-computer interfaces remain quite prescriptive. Commercial applications, e.g., Carma1, Liftshare2, flinc3 and Lyft4, utilize heuristics with social dimensions for enhancing service and issues of trust. However their rigid spatio-temporal constraints remain. For riders (clients) this results in significant issues, such as not knowing the potential limitations of their mobility request on their choice set, thus potentially missing out on rides.

Addressing these issues in previous work [6], we proposed a conceptual ride sharing user interface called OppRide. OppRide replaces the traditional 1-step mobility request with a novel 2-step negotiation. Using our approach, visual feedback describing a client’s pick-up opportunities are communicated in the form of launch pads, derived in response to drop-off constraints only.

The launch pad visualization communicates the system’s global service offering which may come from multiple vehicles. However this earlier work considers a binary perspective only, i.e., delineating those locations affording mobility to the requested drop-off, independent of the client’s location. Whilst this binary approach—serviced versus not serviced—allows a client to get any ride, it does not consider their inherently individualistic route choice behavior [7]. Addressing this issue, we now present an approach to enhance the visualization. We hypothesize that by visualizing additional launch pad information, a client flexible in space can potentially increase their individual route choice utility.

II. AN OPPORTUNISTIC APPROACH

Launch pads form the basis of OppRide, visually communicating a client’s pick-up opportunities. As laid out in previous work [6], launch pads are derived by the central authority in response to a client’s drop-off constraints (location and arrival time window), specified during the first step of the negotiation. From this anchor the authority identifies the relevant set of available vehicles $m$ using their global service coverage map; a representation composed from each active vehicle’s network-time prism, NTP [8]. The NTP is a three dimensional space-time volume $(x,y,t)$ constrained to network space which we interpret describes the vehicle’s service potential.

The authority then derives a space-time slab [9] from each satisfying vehicle’s NTP using the client’s constraints: drop-off at $d$ between now $t_{now}$ and some arrival time $t_d$ with flexibility $t_{flex}$. Projecting the slab $\mathbb{R}^3 \mapsto \mathbb{R}^2$, we derive the vehicle’s vector map, $X$. Aggregating $m$ vehicle maps, launch pads describing the system’s pick-up opportunities $\{p\}$ are issued to the client to choose a discrete pick-up, $p$. To cater for some minimum decision making time [3], we introduce an additional factor, $\alpha$, to the query’s lower bound forming $[t_{now} + t_{\alpha} \cdot d + t_{flex}]$.

Depending on the NTP representation, launch pads can be described using either discrete (point) or continuous (polyline) features which may be bounded (polygon), e.g. convex hull or alpha shape. Receiving launch pads overlaid on a digital map, a client can browse and decide if they are within or outside the service offering. If their location, $l$, is outside, they can determine if they can reach a serviceable location within $t_{d} + t_{flex}$, i.e., services intersect their accessible

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1http://www.carmacarpool.com/
2http://www.liftshare.com/
3http://www.flinc.org/
4http://www.lyft.com/

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region, AR. Towards enhancing this decision process, the visualization of launch pads can include additional dimensions.

III. ADDING DIMENSIONS

Motivated by both a client’s individual route choice behavior [7] and this time sensitive application [3], the launch pad visualization can be enhanced with various information shown in a third dimension. As a spatio-temporal object, the NTP can be extended by both attributing its geometry and linking to additional data. However care is required regarding the handling of the data types and their temporal relations. For this reasons we revisit map algebra theory.

Map algebra was originally designed for use in homogeneous space and relies on a set of appropriate operators for data processing [10]. We now apply it to network space for the visualization of vehicle attributes overlapping in spacetime. This geographic analysis method is commonly used to assess the favorability of space according to some metric. Let the favorability of any location, \( F \), in the output map be evaluated by the function, \( f \), using values at the same location in \( m \) input maps [11].

\[
F = f(X_1, \ldots, X_m)
\]  

(1)

Reviewing potential operators [10] with temporal extensions [12], their suitability in OppRide depends on the input and desired output. Considering a client’s mobility needs we examine two example variables: number of available seats (discrete) and trip-proportional fares (continuous). Drawing on common operators, it makes sense from a client perspective to consider sum or min operators for seats, and a polygonal representation may be sufficient to assist reasoning at certain map scales. In contrast for continuous data varying within the NTP, e.g., fares, average, min or max are more suitable and both a discretized point or continuous polyline representation can be used to describe the choice set.

Various geographic analyses may be used to visualize these new dimensions depending on their data type. For discrete vehicle data, all relevant road portions or bounded geometries would be equally attributed. For continuous movement data, raster interpolation can be used between endpoints of road portions assuming some constant velocity. For this visualization road portions can be buffered and used as bounds for the interpolation or the concept of ixels may be used [13]. The realism of this characterization can be extended using a probabilistic variant of the NTP [14].

IV. OVERVIEW OF RESULTS

Taking a computational approach we use a multi-agent simulation to observe the behavior a client seeking to maximize their individual utility using three different fare models.

In our experiment we consider a uniform \( 15 \times 15 \) grid with supply from multiple vehicles moving between random zones evenly distributed around a central service area [6]. For a single client flexible in space requesting a mobility service, we visualize launch pads according to their fares using three different models: standardized; homogenous in space-time, client centric; varying in space yet fixed over time (equivalent to a taxi meter) and vehicle centric; varying in both space and time (equivalent to ride sharing). Adopting a perspective of individual utility, the client will seek to choose the cheapest reachable location within the launch pads offered. We fix the client’s accessibility in space to one edge only.

Results of the standard fare model mirrors previous work to consider launch pads from a binary perspective [6]. They show here that with greater vehicle population sizes a client moves less distance to get a ride, i.e., their current location increases in probability of pick-up. Enhancing the visualization, results of the client centric model show how a client seeks to travel the limit of their accessibility along paths towards their drop-off, motivated by a cheaper fare. In contrast, vehicle centric fares; varying in both space and time with supply, again show that increases in vehicle population size mean that a client does not move as far. Whilst these two results may appear intuitive, they provide clear justification for the visual interface—with additional information a client flexible in space can maximize their individual utility during uncertainty; both service supply and their knowledge thereof.

For a full explanation of the launch pad concept, experiment design, results and future work, refer to our poster.

V. ACKNOWLEDGMENTS

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REFERENCES


