Flexible decision making under uncertainty for intelligent mobility on-demand

Michael Rigby and Stephan Winter

Department of Infrastructure Engineering
The University of Melbourne, Australia
rigbym@student.unimelb.edu.au, winter@unimelb.edu.au

Abstract. Interacting with dynamic ride sharing systems for ad-hoc travel is a complex spatio-temporal task. The uncertainty of service supply and demand in this constrained arena challenges the rigidity of traditional human-computer interfaces. Without knowledge of service potential or the effect of their own limiting constraints, clients may simply not find any matching ride. Previous work on an intuitive interface concept, launch pads, resolves this issue by providing clients with visual feedback during a novel 2-step negotiation. Whilst computationally valid, human understanding of the launch pad metaphor and its interaction design still has to be assessed to close the system’s feedback loop. For this purpose usability testing of launch pads is proposed in a directed wayfinding scenario. Results of testing will allow tuning of the system towards validation of the proposed visualization.

Keywords: Intelligent transportation systems, ad-hoc ride sharing, human-computer interaction, spatial cognitive engineering

1 Introduction

New sensing and communications technologies are inspiring the design of innovative, shared ride transportation systems [25, 12], e.g., autonomous vehicle ride sharing. Using novel location based services integrating advanced traveler information, users can search for and discover opportunities satisfying their intentions in space-time [19], moving us closer towards realization of an intelligent Mobility Internet [14].

Existing human-computer interfaces for ad-hoc ride sharing however are rigid. They rely on the full and a priori disclosure of trip information from persons to perform ride matching [6]. For a user (client), this presents two significant issues. Firstly, disclosure of trip information before knowing the system’s capacity to respond presents a privacy issue. Secondly, without feedback a client may not be aware of the systems current state, e.g., during low service coverage, or the potential limitations of their request. Consequently they may make iterative, uninformed queries across space-time and sub-optimal choices.

Due to the inherent variability of service supply and demand in ad-hoc ride sharing, travel planning in this complex and dynamic system can be uncertain.
To assist client reasoning and decision-making, we address both issues in previous work [20], developing a conceptual ride sharing user interface called OppRide. OppRide replaces the traditional requirement that all information be submitted in one step, with a novel 2-step negotiation. Using our approach, visual feedback describing a client’s matching pick-up opportunities is communicated in the form of launch pads. The visualization is derived in response to a client’s drop-off constraints only, allowing the subsequent pick-up choice to be flexible in both space and time (Fig. 1). This directed wayfinding approach [15] may also be extended to alternative interaction scenarios.

Launch pads are quantitative representations of vehicle service potential drawn from time geography research. Aggregated from slabs [11] derived from each matching vehicle’s network-time prism [13] according to a client’s drop-off constraints (location and arrival time window), launch pads describe OppRide’s global service offering which may come from multiple vehicles. Contrasting a client’s successful negotiation using launch pads against a traditional approach using shortest path calculations, e.g. [5], the OppRide interaction design yields the same result given that in retrospect the launch pads derived will always intersect the requested pick-up. By revealing information incrementally a client’s location privacy is preserved until a formal contract is made.

The launch pad visualization facilitates a client’s flexible decision making under uncertainty in a manner offering them choice—a factor critical in mobility. The focus of this study is to determine to what degree the launch pad metaphor is understandable and usable by client users within ad-hoc ride sharing. Whilst the concept is valid computationally, we will seek to validate the OppRide interface design by conducting human usability testing. We hypothesize that a discrete point representation of launch pads is both easier to understand and use for pick-up choices in on-demand mobility compared to a continuous representation. Understanding the complexity of route choice behavior in mobility, the study presented in this paper is preliminary only and focuses on decision making based on the presentation of alternative visual interfaces.

![Fig. 1. OppRide feedback during the 2-step negotiation.](image-url)
2 Feedback

The OppRide interaction design is drawn from both transportation and spatial cognition research [20]. The negotiation constitutes a feedback loop [24], to provide clients with improved situation awareness via a user-centered design [4].

Compared to a traditional visualization (e.g., Fig. 2a), when launch pads are visualized as two-dimensional (point, polyline or polygon) features, a client’s initial reasoning is binary: is their current, private location or accessible region within or outside the system’s service offering? From here a decision can be made, e.g., wait at the current location or trade time for space and move to a more serviceable area (Fig. 2b). This simple approach already overcomes the case of a client failing to get any ride due to a lack of knowledge and matches. By considering a client’s flexibility in space and time, the interface’s time window approach provides a relevant choice set [22] whilst reducing display clutter [1].

Extending this further, enhancement of the launch pad visualization to a third dimension (point, polyline or polygon), may allow a client to adjust their intention within the constraints of the service offering. Drawing on route choice behavior research [3], additional factors, e.g., seating or fare, can be visualized using, e.g., a color ramp, to directly address a client’s mobility needs (Fig. 2c,d)[21]. With added information a client can seek to maximize their potential individual utility [2], thus leading to optimal decisions. The effect of this added information and its cognitive loading [17] will be examined in our study.

Towards minimizing OppRide’s gulfs of evaluation and execution [16, 18], we now describe our usability test.

![Fig. 2. Example visualizations: traditional (a) 2D vehicle routes (point, polyline and discrete) and launch pads (b) 2D service area (polygon and discrete), (c) 3D seating (polygon and discrete), (d) 3D fare (polyline and continuous; cyan = low, magenta = high). Visualizations derived from two vehicles satisfying the client’s drop-off.](image)

3 Usability Testing

According to seminal usability theory [7], testing of the OppRide interface design must consider the psychology of human-computer interaction together with the psychology of wayfinding. Whilst maps can be understood by humans [11],
understanding and use of the launch pad metaphor in navigation scenarios [15] needs to be gauged.

For this purpose we will test 20 users from a range of profiles, deeming this sample size to be sufficient [23]. Integrating usability, user utility and cognitive loading, our research applies the PACMAD model [8], interpreting cognitive loading from a visualization and spatial cognition perspective. The usability test is performed using a prototype version of the OppRide interface, developed using the Google Maps API\(^1\) for its interactive map functionality and capacity to overlay launch pads. The test will be conducted outdoors using a mobile device for reasons of relevance and interaction using a common touch screen interface.

The test will survey participant preferences and choices using the point and polyline launch pad variants only (we exclude the polygonal representation in this preliminary study as the generalization is not directly comparable). Commencing with a short animation introducing the OppRide concept, the test then narrows participation with the following statement: You intend to travel using OppRide to a local shopping center 5 from now. You are one person and your luggage consists of a backpack only. You are standing at 15 Theodore Street, Flora Hill in Victoria. You have submitted your drop-off information using OppRide and have just received launch pads overlaid on a digital map describing your matching pick-up opportunities in the next 5-10 minutes. From this information, please browse, reason and choose a pick-up option by clicking your desired location on the map within the launch pads shown.

The first task asks participants for their preference for either 2D (x,y) point or polyline launch pads in 10 different un-timed scenarios using the statement above. Scenarios visualize launch pads in different network geometries with varying levels of service coverage (refer [20]). In the next two tasks participants are asked to choose a pick-up location in 10 different scenarios and responses are timed. The first of these asks participants to choose a pick-up location from a 2D (x,y) point then a polyline launch pad. The second task uses 3D (x,y,color:fare) launch pads in the same scenarios, yet randomizes the ordering of the variants to minimize any bias arising from a previous choice.

To assist decision making regarding access distance and time to launch pads in the 5 minute (lower bound) window, an additional spatial analysis (accessibility) tool is made available in the interface. This facility allows the test to focus on aspects of spatial cognition relating to visualization and choice rather than perceptions of space-time which are more complex, e.g., [10, 9].

The usability test’s observations include:

- Preferences for point or polyline
- Decision times using 2D and 3D variants
- Use of zoom and pan map functions
- Observed behavior: interaction and confidence
- Participant assessment concluding the test

Analysis will compare participant preferences for the launch pad variants against their decision times.

\(^1\) http://developers.google.com/maps/
4 Closing the loop

Results from the usability test are expected to commence closure of the OppRide feedback loop. By establishing preference for and understanding of the launch pad variants, it is expected that with the increased knowledge a client can make better decisions in ride sharing.

Due to the dynamism of ride sharing, future work will consider the stability of launch pads in different network geometries and supply-demand conditions. From here a minimum bound (time horizon) can be ascertained for a client’s interactions during the negotiation process (refer mental affordances [19]).

Additional future work from this study includes the use and structuring of launch pad variants; catering for issues of scale and granularity using, e.g., map zoom levels, and finalizing and testing a full featured OppRide interface. Further behavioral issues relating to client flexibility in space-time, the effects of additional launch pad dimensions, e.g., seating, on individual utility and the use of OppRide in a mobile environment are deemed to be outside the scope of the current study, yet will be considered in future work.

Results of the usability test and a technical poster describing the OppRide architecture and launch pads will be presented at the workshop.

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References