Towards Explainable Recommendations of Resource Allocation Mechanisms in On-Demand Transport Fleets

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Context and motivation

On-Demand Transport

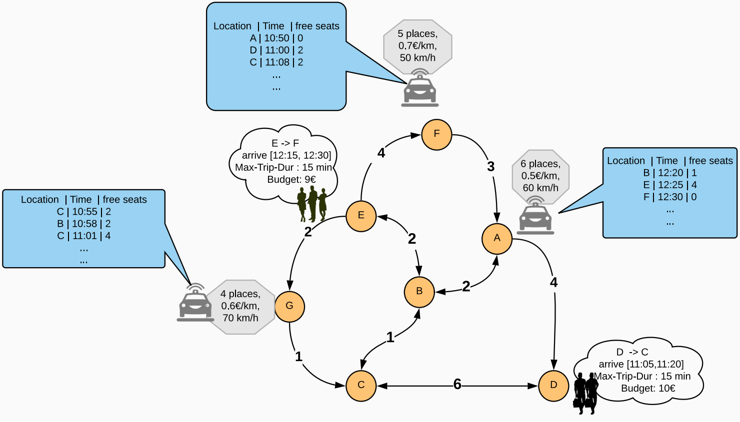


Figure 1: Dial A Ride Problem (DARP)

Existing approaches

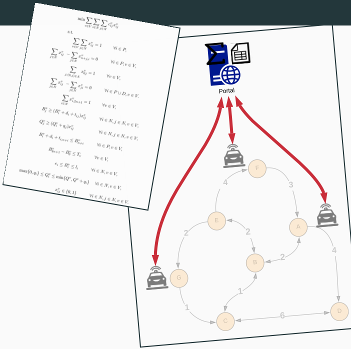
Centralized dispatching

- Requests are centralized in a portal
- Linear/ Mixed integer program models

  ⇒ NP-Hard problem, lack of scalablity

- Continuous access to the portal

  ⇒ expensive with a critical bottleneck



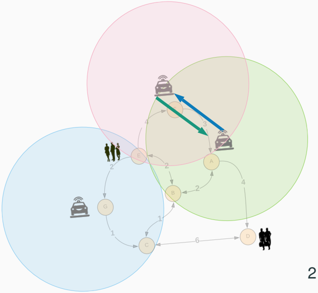
Decentralized allocation

- Decentralized autonomous decisions

  ⇒ need for conflict detection and avoidance protocols

- peer-to-peer (P2P) communication

  ⇒ need for scalable communication model to ensure best information sharing



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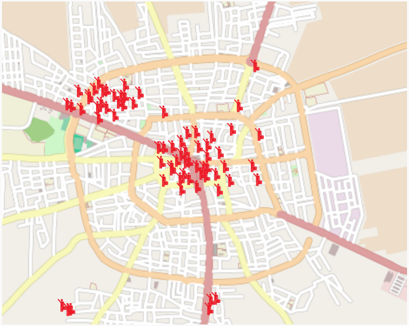
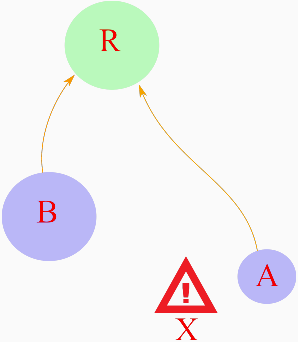
About the Need for Explainability



Demand distribution at rush hours



Emergency scenario

Contribution

A generic model to ODT's dynamic resource allocation problem
Extends the Online Localized Resource Allocation (OLRA) [Zargayouna et al., 2016] by considering Autonomous Vehicle (AV) fleets with communication constraints

$$\langle \mathcal{R}, \mathcal{V}, \mathcal{G}, \mathcal{T} \rangle$$

- $\mathcal{R}$: a dynamic set of requests
- $\mathcal{V}$: a fleet of m vehicles
- $\mathcal{G}$: a graph defining the road network
- $\mathcal{T}$: the problem's time horizon

Communication range and direct connectivity

Vehicles communicate within limited communication range

$$\texttt{d\_ctd} : \mathcal{V} \times \mathcal{V} \times \mathcal{T} \rightarrow \{0, 1\}$$

defines if two vehicles are connected directly to each other

$$\texttt{d\_ctd}(i, j, t) = \begin{cases} 1, & \text{if } \mathit{distance}(\texttt{loc}_i^t, \texttt{loc}_j^t) \leq r : r = \mathit{min}(\mathit{rng}_i, \mathit{rng}_j) \\ 0, & \text{otherwise} \end{cases}$$

Transitive connectivity

To maximize their connectivity, two vehicles can be connected transitively

$$\texttt{ctd} : \mathcal{V} \times \mathcal{V} \times \mathcal{T} \rightarrow \{0, 1\}$$

generalizes the `d_ctd` with the transitive connectivity.

$$\texttt{ctd}(i, j, t) = \begin{cases} 1, & \text{if } \texttt{d\_ctd}(i, j, t) \text{ or } \exists k : \texttt{ctd}(i, k, t) \& \texttt{ctd}(k, j, t) \\ 0, & \text{otherwise} \end{cases}$$

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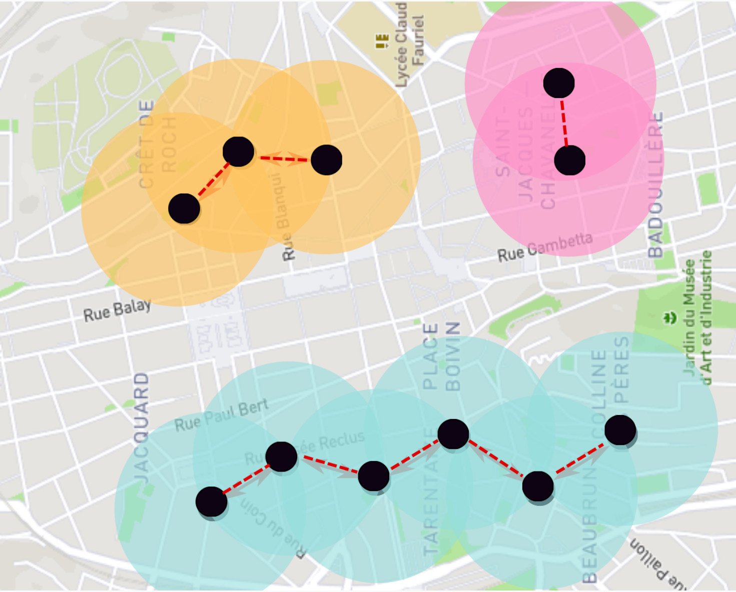
Connected sets

A connected set is a set of entities that are connected directly or by transitivity.

$$CS : \mathcal{V} \times \mathcal{T} \rightarrow 2^{V}$$

$$CS(i, t) = \{j \in \mathcal{V} | ctd(i, j, t)\}$$

The connected sets are dynamic entities; they are created, split, merged at run-time based on the vehicles' movement.
A vehicle v may communicate at time t only with the members of its connected set by directed or broadcast messages.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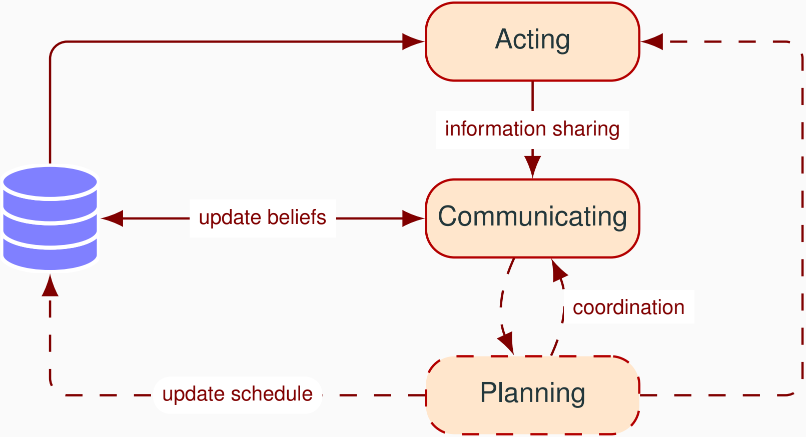
Rue Paul Bert
Reclus
TARENTAIZE
COLLINE PÈRES
BEAUBRUN
Rue du Coin

Generic vehicle behavior



AV-OLRA Solutions

A solution for AV-OLRA is defined for each connected set as an aggregation of the allocations of all vehicles in this set, avoiding all conflicts that could happen. Solution methods depend mainly on the adopted coordination mechanism (CM):

$$CM := \langle DA, AC, AM \rangle$$

- *DA*: level of decision autonomy $\Rightarrow$ centralized (*C*) / decentralized (*D*)
- *AC*: agents' cooperativeness level $\Rightarrow$ sharing (*S*) / no-sharing (*N*)
- *AM*: the allocation mechanism $\Rightarrow$ *GREEDY* / *MILP* / *DCOP* / *AUCTIONS*

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Implemented coordination mechanisms

- *Selfish*: $\langle D, N,\text{Greedy}\rangle$ [van Lon et al., 2012]
- *Dispatching*: $\langle C, S,\text{MILP}\rangle$ [El Falou et al., 2014]
- *Auctions*: $\langle D, S,\text{Auction}\rangle$ [Daoud et al., 2020]
- *Cooperative*: $\langle D, S,\text{DCOP}\rangle$
  MGM-2 solver [Pearce and Tambe, 2007]
  DSA solver [Zhang et al., 2005]

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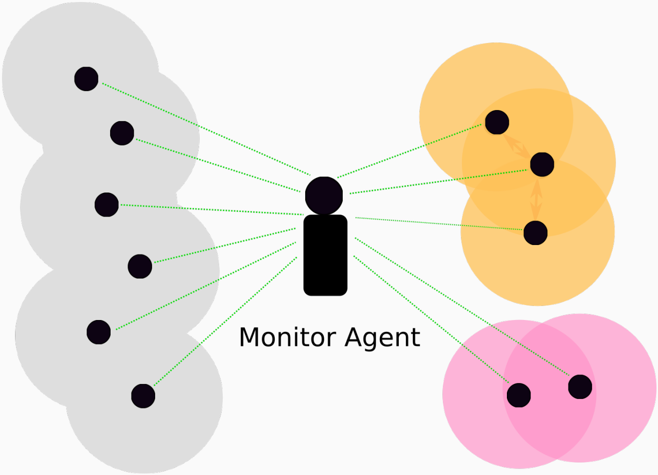
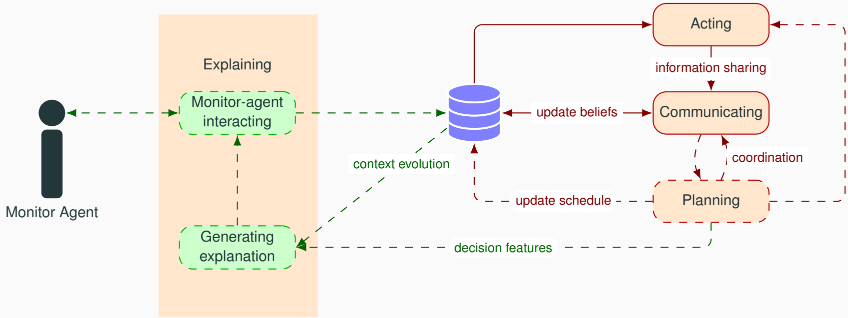
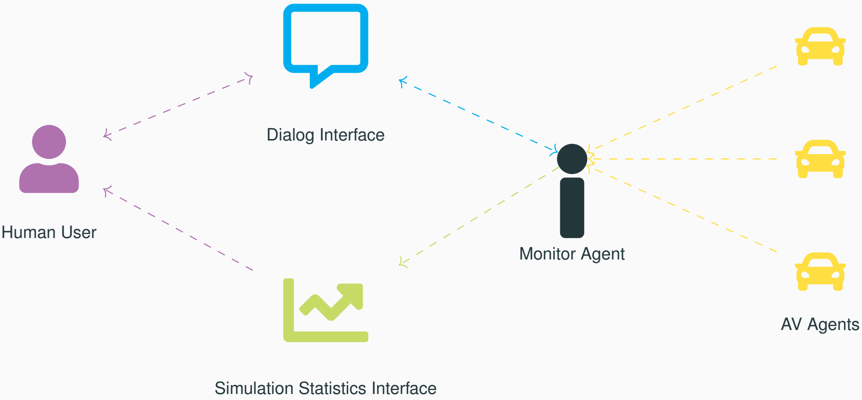
Monitor Agent (MA)



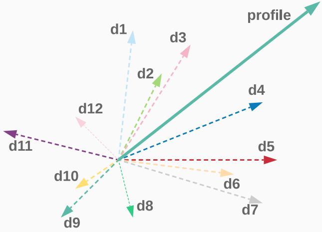
AV explaining sub-behavior

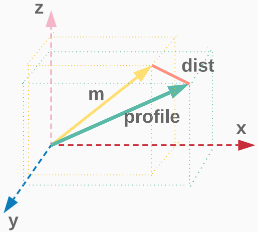


MA interaction model



Computing the recommendations





$$dist(m, p) = \sqrt{\sum_{i=1}^{n} (m_i - p_i)^2}$$

$$sim(m, p) = \frac{1}{dist(m, p)}$$

Creating explanations

AV individual actions

- Whenever an *AV* take an explainable decision
- *AV* interpret his behaviors, justify the decisions with the social and technical reasons behind
- Interpretation are communicated to *MA*
- The set of explainable *AV* decisions depend mainly on the solution method adopted by *AV*s

Solution	*DA*	*AC*	*AM*	**Explanation examples**
Selfish	*D*	*N*	Greedy	Why prioritizing a specific request?
Dispatching	*C*	*S*	MILP	Which constraints are violated?
Market	*D*	*S*	Auctions	How winner determination computed?
				Why accepting some trade options?
Cooperative	*D*	*S*	DCOP	What are individual costs and utilities?

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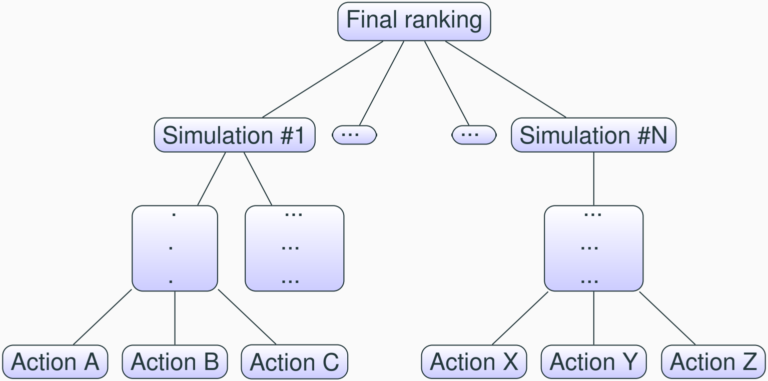
MA's aggregated decisions



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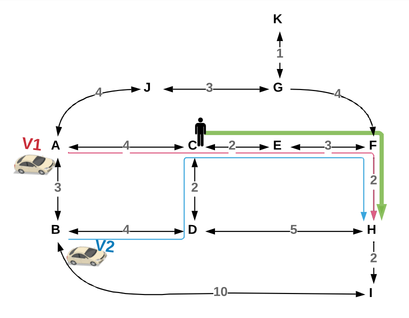
Illustrative examples

Explaining AV individual actions with Auctions



V1: “Serving d_1 costs 11 time units because reaching *C* from my current location *A* requires 4 time units, and reaching *H* from *C* requires at least 7”

V2: “Serving d_1 costs 13 time units because reaching *C* from my current location *B* requires 6 time units, and reaching *H* from *C* requires at least 7"

V1: “I win the auction because my offer has a lower cost than V_2’s. The lower the cost is, the better the *QoB* achieved."

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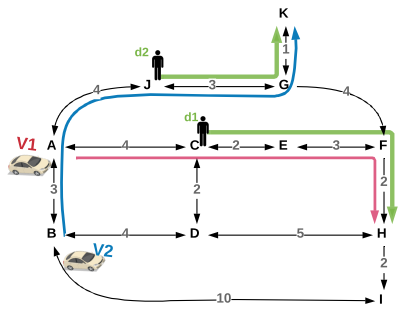
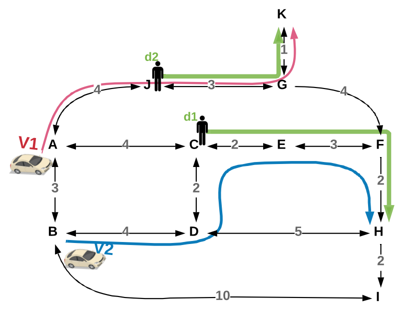
Explaining AV individual actions with Auctions (cont.)





V1: “Abandoning d_1 in favor of V_2 decreases the global operational cost value by 1. It also decreases the accumulated waiting time by 1”

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Explaining commulated results

Abstract features

“greedy method favors closer requests with short distances, which means lower operational cost.”

“centralized dispatching requires continuous communication between vehicles and the dispatching portal, this consumes bandwidth in dynamic settings”

Explaining commulated results (cont.)

Scenario evolution

Example : QoS oscillation during a specific time slot

“At the specified time slot, 70% of vehicles were carrying passengers on the route to their far destinations, only a low number of requests is satisfied, meaning low values of QoS for a while; when these long trips ended one by one, the number of satisfied requests increases rapidly causing the peak in QoS.”

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Conclusion

Summary

Our contribution

- A multi-agent model of explainable ODT system
- A generic model for solution methods
- Extension with agent behavior interpretation
- Tree shaped aggregation of explanation for flexible interaction granularity
- Implementation guidelines for the explainable recommender system

Thank you!

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