Approches multiagents pour l’allocation de courses à une flotte de taxis autonomes

Gauthier Picard    Flavien Balbo    Olivier Boissier

Équipe Connected Intelligence/FAYOL
LaHC UMR CNRS 5516, MINES Saint-Étienne

5 Juillet 2017
Outline

- Context
- Problem modeling
- Multiagent solution modeling
- Evaluation
- Conclusion
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Context

New Service by Autonomous Vehicles

- **Light Autonomous Vehicle**
  - Big site internal service
  - Last miles shuttle
  - Suburban service
  - Interstice shuttle

- **Heavy Autonomous Vehicle**
  - Automatization of existing bus lines
  - Automatization of public transportation lines

Source: Rapport « ETUDE DES IMPACTS DE LA VOITURE AUTONOME SUR LE DESIGN DU GRAND PARIS »
Context

Fleet of Autonomous, Connected Taxis

Taxis handling the travel requests
• take autonomous decisions
• communicate through inter-vehicular network (VANET) or portal

Compare allocation strategies to satisfy 90% of travel requests in a context of VANET communication and decentralized allocation process
Context

Assessment Criteria

- Quality
  - Quality of Service
  - Average waiting time
  - Gain

- Scalability
  - Number of messages
  - Processing time

SWARM interactive solution

for Saint-Etienne city
Theoretical background
- OLRA (Online Localized Resource Allocation)
- MAOP (MultiAgent Oriented Programming)
- DCOP (Distributed Constraint Optimization Problem)
- Self Organization Models
- MABS (MultiAgent Based Simulation)

Results
- Models
  - OLC²RA: OLRA extension for communication constraints
  - RSP (Renault Swarm Problem): OLC²RA specialization
  - Multiagent Allocation Model
  - Multiagent strategies: modeling multiagent decision process
- Simulation platform
  - Adaptation to the Swarm project constraints
- Experiments & Analyze
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Problem modeling

Problem components

- Transportation network
  - Graph of nodes and edges
  - Edge with several locations
  - Predefined set of source and destination nodes of travelers

- Traveler request
  - Spatial parameters: origin, destination
  - Temporal parameters: time window of validity

- Taxi
  - Spatial parameters: location, destination
  - Communication parameter: fixed communication range
The communication range is similar for taxis and sources

Connection relation definition
- Distance between two taxis is inferior to the communication range

Creation of sets of connected components thanks to the transitivity property of the connection relation.
- Composition: connected taxis and sources
- Property: Inside a connected set, taxis receive the same messages
Problem modeling

Problem definition

- **Taxi Allocation Problem (TSAP):** online allocation of active requests to riding or not taxis for a specified communication infrastructure minimizing costs and maximizing quality of services for a period of time

- **TSAP(t):** allocation of active requests at time \( t \)
  - *With a linear programming formalism:*

\[
\min_{v_{ij}^t} \sum_{v_{ij}^t} c_{ij}^t v_{ij}^t
\]

\text{avec}

\[
\forall i \in A \quad \sum_{j \in R \cup \{0\}} v_{ij}^t = 1
\]

\[
\forall j \in R \quad \sum_{i \in A} v_{ij}^t \leq 1
\]
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Generic simulated taxi agent behavior
1. Reads messages
2. Updates believes about requests and taxis
3. Decides next destination
4. Drives to one step to the destination
5. Sends messages about requests and taxis

Decision process
- Filters Request (delete not satisfiable requests)
- Computes request assessment
- Chooses the best
Similar cooperative request ranking criteria

- **The ratio of taxis which are further of the source:** A taxi chooses the requests which penalize other taxis if it is not chosen by him.

- **The ratio of travelers who are waiting less than the traveler of the request r:** A taxi chooses the request which is the more penalized if it is not chosen by him.

\[
\kappa_{\text{dist}}^{\text{coop}}(v_i, r_j, t) = \frac{1}{\text{closerFree}(v_i, r_j, t) + \text{closerRiding}(v_i, r_j, t) + 1}
\]

\[
\kappa_{\text{time}}^{\text{coop}}(v_i, r_j, t) = \frac{\text{free}(v_i, t)}{\sum_{r_k \in KR(v_i, t)} \text{worst}(\text{pos}(v_i, t), r_k, r_j, t) + 1} - \frac{(1 - \text{free}(v_i, t))}{\sum_{r_k \in KR(v_i, t)} \text{worst}(\text{dest}(r_j, t), r_k, r_j, t) + 1}
\]
Multiagent solution modeling
Proposed allocation process solution

- **d_alloc solution description**
  - Each taxi decides on its requests
  - Coordination is done connected set by connected set with a DCOP approach
  - Allocation is challenged at each time step

- **DCOP resolution**
  - **Objective**
    \[
    \min_{v_{ij}} \sum_{i,j} c_{ij}(v_{ij}) + \sum_{C \in CSet_{A}(t)} \sum_{r_j \in KR(C,t)} AMO_{ij}(v_{ij}, \ldots, v_{|C|j})
    \]
  - **Protocol:** Max-Sum
Multiagent solution modeling
Proposed allocation process solution
Multiagent solution modeling
Comparative allocation process solution

- **p-alloc** Solution description
  - A portal contains all active requests
  - Taxis pick their chosen request at portal
  - Allocation is never challenged
Multiagent solution modeling
Comparative allocation process solution

- **c-alloc** Solution description
  - A global infrastructure of communication supports the collection of taxi locations and allocation decisions.
  - A central dispatcher allocates optimally requests to taxis
  - Allocation is challenged at each time step

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Optimal allocation system

Bidirectional communication
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Results

Experimental Conditions

Experiments

- 13 combinations
  - Taxi Decision process
  - Request information infrastructure: VANET, Portal
  - Allocation location

Topology
- City: Saint Etienne
- Distance between sources: {1.6, 3, 4} km

Taxi:
- Number: between 8 and 20
- Simulated speed: 30 km/h
- Communication range between 0,25% and 16% of the total surface area(similar to the sources)

Simulation
- One simulation cycle equivalent to 5 seconds
- duration: 3,5h (2500 cycles), 4h (3000 cycles) or 8h (6000 cycles)

Request
- [0; 2] requests by cycle
- Request scenario
  - *Uniform*: uniform random choices of the origin and destination requests
  - *Concentrate*:
    - S1 is the origin of 50% of the requests
    - every 100 cycles creation of [1, 6] requests at source S1
  - *Decoupled*: S1 cannot be the origin of a request

Energy
- Autonomy: 100 Km (2325 cycles), 215 Km (5000 cycles)
- Recharge duration: 30 min (360 cycles)
Evaluation

Quality

![Graph showing QoS vs nb_taxis for different allocation ranges.]
Evaluation

Quality
Evaluation

Quality

![Graph showing gain vs. nb_taxis with various allocation ranges]
Evaluation

Scalability

![Graph showing simulated time against number of taxis (nb_taxis) for different allocation methods and ranges.](image)
Evaluation

Scalability

![Graph showing scalability analysis](image)
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Conclusion

- Three allocation strategies were compared
- Quality results of the DCOP proposal are quite similar for QoS measure and better for average waiting time measure
- Centralized solutions are penalized with several taxis for Scalability measure