

Mobilita 200 - Report

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Reference

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Short Mission: STSM within the Autonomic Road Transport Systems COST Action (TU1102)

The Mission

The agent-based systems are an emerging choice for modelling new generation systems based on smart actors and their intelligent coordination, promoting the autonomy of the actors and the clear separation of local decision making and the global cooperation. We believe that such an approach is very relevant for the future of transportation as it ties well with the shift seen all over the industry towards the internet of things, smart objects and decentralized control systems.

As a central goal of this proposal we thus aimed at developing some key extensions with respect to our ongoing effort in developing efficient agent-based routing algorithms. Based on our previous work we specifically aimed at:

- Improving the efficiency our agent-based algorithm presented previously in [1, 2, 3]
- Discussing the relevance of Agent-based systems with experts from the ARTS project (Autonomic Road Transport Systems - COST Action TU1102)
- Promoting future collaboration by networking activities

Work and Contributions

During the visit a number of networking activities promoting the scientific exchange between the participants was carried out. Also importantly, in the meantime we were able to develop key improvements to our agent-based VRPTW algorithm yielding new state-of-the-art results, presenting a valuable contribution.

Research Carried Out: The key contribution developed within this mission is the extension to our algorithm solving the Vehicle Routing Problem with Time Windows (VRPTW) by means of agent negotiation [1, 2, 3]. These extensions contribute to a very significant improvement in the overall algorithm quality providing for a valuable contribution that is likely to attract attention of the international scientific community.

Specifically, over the two most relevant VRPTW benchmarks of Solomon and Homberger-Gehring [4, 5] being widely used within the Logistics and Operation Research community we were able to reduce the relative error of the algorithm with respect to the primary optimization criteria (minimization of the number of routes) from 2.4% reported by [3] to a mere 1% relative error. Also, we were able to equal the solution quality provided by the state-of-the-art classical centralized algorithms in over 84% of the cases. Underlining the significance of these results is the fact that they represent the current state-of-the-art with respect to agent-based algorithms for VRPTW, significantly improving on all previously presented agent-based algorithms.

Key to these achievements is the adoption of a novel negotiation semantics within the negotiation process carried out between the individual agents representing the individual vehicles. The novel negotiation semantics is based on enabling the agents to commit to serving customers even when such a commitment would result in the violation of either the capacity or the time-windows constraints inherent to the solved problem, with the feasibility of the corresponding routes then being restored by ejecting some other customers. The choice of the particular tasks to be ejected is guided by a novel heuristics that strongly promotes the diversification of the ongoing search process. Together these two contributions provide means for the overall search strategy to traverse also the infeasible search space providing means to effectively escape local minima and thus enable the significantly improved performance of the algorithm.

Publications:

The following publications were submitted based on the mentioned research:

- Petr Kalina, Jiří Vokřínek and Vladimír Mařík: The Art of Negotiation: Developing Efficient Agent-based Algorithms for Solving Vehicle Routing Problem with Time Windows - to appear at the 6th International Conference on Industrial Applications of Holonic and Multi-Agent Systems HOLOMAS 2013, August 26.-28.2013, Prague, Czech Republic

Meetings and Networking: A number of social/networking activities was carried throughout the visit in order to both formally and informally bridge the gaps between the research tracks of individual project participants and exchange scientific experiences in fields relevant to the ARTS project:

- Our research track - *Solving VRPTW by means of Agent Negotiation* - and its relevance within the Autonomic Transport Systems in general was discussed with the ARTS participants within a dedicated seminar, including the project leader and STSM host Thomas Leo McCluskey as well as other participants e.g. Falilat Jimoh, Shahin Shah, Lukas Chrapa and Mauro Valati.
- Two talks on *Modelling Road Traffic Incident Management Problems for Automated Planning* and *Symbolic Representation of Road Traffic Domain for Automated Planning to Manage Incidents* were given by Shahin Shah being very relevant from the perspective

of modelling, providing a classical planning view of the domain, rather than the agent-based decomposition inherent to our research.

- A number of other interactions was carried out with respect to the relation between the classical planning and the distributed planning and problem solving featuring also for example in [6] that we believe is a very interesting and relevant problem area with respect to ARTS.
- A number of other networking activities e.g. informal meetings, active participation in the university social, cultural and sport activities etc. took place as well further enriching the networking aspects of the mission.

In overall I consider the visit to be extremely fruitful in terms of expanding my scientific network, integrating the ARTS participants, gathering novel views on my research and exchanging ideas. The visit also presented yet another valuable step in creative collaboration between the host university and my home institution - the Czech Technical University - also participating in the ARTS project.

I expect further collaborations to emerge as a result of this initiative e.g. as part of my participation on the 1st Summer School of Autonomic Road Transport Support Systems taking place this summer in Paris.

Conclusion and Future

I consider the six weeks spent at the University of Huddersfield within the ARTS project extremely fruitful and enriching. The head to head formal and informal meetings enabled us to view our particular research domains in broader perspectives, exchange interesting ideas and articles, showcasing our respective contributions and most importantly to become friends and colleagues. For me, being an early career researcher, these accomplishments are extremely valuable as well as the insight into cultural and social similarities and differences between the scientific universe as perceived from our respective regions and cultures.

Apart from networking and collaborating, I was also able to advance significantly within my own research, exploring novel approaches within the agent negotiation based solving approaches yielding new state-of-the-art results within an area closely related to the ARTS core domains and project goals.

References

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- [2] **Parallel Solver for Vehicle Routing and Pickup and Delivery Problems with Time Windows Based on Agent Negotiation**, Kalina, Petr and Vokřínek, Jiří, Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, SMC 2012, Seoul, S. Korea

- [3] ***Improved agent-based Algorithm for Vehicle Routing Problem with Time Windows using Efficient Search Diversification and Pruning Strategy***, Kalina, Petr and Vokřínek, Jiří, Proceedings of the AILog workshop of the 20th European Conference On Artificial Intelligence, ECAI AILog 2012, Montpellier, France
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- [5] ***A two-phase hybrid metaheuristic for the vehicle routing problem with time windows***, Homberger, J. and Gehring, H., European Journal of Operational Research, 2005.
- [6] ***From one to many: Planning for loosely coupled multi-agent systems***, Brafman, R. I. and Domshlak, C., Proceedings of the ICAPS Conference, 2008