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Aims and Scope
The periodical *Dagstuhl Reports* documents the program and the results of Dagstuhl Seminars and Dagstuhl Perspectives Workshops.
In principal, for each Dagstuhl Seminar or Dagstuhl Perspectives Workshop a report is published that contains the following:

- an executive summary of the seminar program and the fundamental results,
- an overview of the talks given during the seminar (summarized as talk abstracts), and
- summaries from working groups (if applicable).

This basic framework can be extended by suitable contributions that are related to the program of the seminar, e. g. summaries from panel discussions or open problem sessions.

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Executive Summary

Contributions

3.15 Collaborative Mission Planning for Autonomous Maritime Vehicles

Paulo E. Santos (Flinders University – Adelaide, AU)

Joint work of Paulo E. Santos, Karl Sammut
Main reference Thiago Pedro Donadon Homem, Paulo Eduardo Santos, Anna Helena Reali Costa, Reinaldo Augusto da Costa Bianchi, Ramón López de Mántaras: "Qualitative case-based reasoning and learning", Artif. Intell., Vol. 283, p. 103258, 2020.
URL http://dx.doi.org/10.1016/j.artint.2020.103258

The exploration of unknown environments, often presents unforeseen challenges and inherent risks due to the uncertainties involved. While single autonomous systems are capable of completing complex missions, the introduction of multi-robotic teams can permit increased level of efficiency to a given task, especially when these tasks cover large areas and mission completion time is a critical constraint. The use of heterogeneous robotic teams of autonomous underwater vehicles (AUVs), autonomous surface vehicles (ASVs) and seabed crawler vehicles can further facilitate a higher degree of flexibility and redundancy when analysing complex environments under diverse environmental conditions. The challenge of traditional autonomous-vehicle team-based localisation and control techniques are, however, considerably magnified in the underwater domain by the lower reliability and potential asynchronicity of underwater acoustic communications as compared to RF based communication in the above water domain. This complicates possible mission tasking approaches for hybrid teams of autonomous marine vehicles in terms of obtaining a shared understanding of the environment and the team status, thus requiring new solutions for control, coordination, collaboration and communication to overcome these complications.

This brings the need to investigate efficient reasoning processes, communication strategies and underlying low-level control mechanisms necessary to coordinate heterogeneous teams of autonomous marine vehicles, in dynamic and uncertain environments. An underlying assumption of this work is that the autonomous agents have to achieve a common agreement, via a negotiation procedure, in order to solve complex problems collaboratively. Our aim is the development of a mixed-initiative system [1], where the interaction and negotiation between the agents will maximise their resources in order to optimise the successful execution of a common task. The negotiation procedure between vehicles will be conducted in game-theoretic terms [4], where the agent interaction is modelled as a cooperative game and the Nash equilibrium (representing the agents' agreement) will be obtained by online distributed algorithms [3]. This provides efficient task allocation solutions that can be easily extended to consider outside threats along with team collaboration, where the interactions with additional agents are modelled as a non-cooperative game [5]. Negotiation, however, occurs only when there is some level of conflict in the perceived states, assigned actions across the team and the availability of resources within the heterogeneous team. To obtain an efficient problem solving policy for any given problem we propose to use a novel algorithm, Qualitative Case-Based Reasoning and Learning (QCBRL) [2]. In QCBRL, cases are predetermined solutions for groups of autonomous agents (represented as QSR formulae) that could be adapted to similar situations. A reinforcement learning (RL) module enables the team of agents to learn new solutions to unforeseen situations at runtime, without assuming a pre-processing step. Extending QCBRL with the game-theoretic delegation model to a team of underwater vehicles is one of the main tasks to be executed. The project should bridge the gap between current QSR laboratory experiments to large-scale robotics application.

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2 Thiago Homem, Paulo E. Santos, Anna H. Reali Costa, Reinaldo A. C. Bianchi, and Ramon Lopez de Mantaras. Qualitative case-based reasoning and learning. *Artificial Intelligence*, 283:103258, 2020.

3 K. Lu, G. Li, and L. Wang. Online distributed algorithms for seeking generalized nash equilibria in dynamic environments. *IEEE Transactions on Automatic Control*, pages 1–1, 2020.

4 Simon Parsons and Michael Wooldridge. Game theory and decision theory in multi-agent systems. *Autonomous Agents and Multi-Agent Systems*, 5:243–254, 09 2002.

5 Cheng-Kuang Wu and Xingwei Hu. A game theory approach for multi-agent system resources allocation against outside threats. *Journal of Risk Analysis and Crisis Response*, 9, 11 2019.

3.16 Conceptual Transformations of Spatial Information

Simon Scheider (Utrecht University, NL)

Main reference Simon Scheider, Jürgen Hahn, Paul Weiser, Werner Kuhn: "Computing with cognitive spatial frames of reference in GIS", Trans. GIS, Vol. 22(5), pp. 1083–1104, 2018.
URL http://dx.doi.org/10.1111/tgis.12318

Conceptual models of space are required to model spatial reference in natural language processing, orientation in spatial cognition, as well as to make effective use of spatial information for answering questions. Yet, such models often seem limited in accounting for and distinguishing the different ways how space can be conceptualized. One reason seems to lie in our inability to assess the possible transformations of the concepts underlying spatial information. Therefore, future research should study *transformation models* for those concepts that are constitutive of spatial information, including the core concepts of location, field, object, event and network.

Transformations lie at the core of spatial reference systems. For example, to understand a location of a particular *coordinate reference system*, we can express it as a series of transformations starting from a common frame, e.g. from a geocentric Cartesian frame using ellipsoidal angles and projection equations. This fundamental observation applies equally to *cognitive reference frames*. Frames enable orientations in the wild, as well as interpreting spatial references in natural language texts. For example, to move towards the specified location, an intrinsic spatial reference such as "in front of the church" may need to be transformed into an allocentric overview map, and finally into an egocentric frame. Likewise, "mapping" spatial references in texts onto a geographic map requires suitable cognitive transformations into a coordinate reference system. To this end, we need to account for the *diversity of linguistic frames*. Frames frequently go beyond the classical Euclidean strategies (as used by Levinson), including zonal strategies (neighbourhoods around and within objects), topological strategies (inside, outside, etc.), as well as linear referencing strategies (distance along a path) (see Table 1). Transformation models could therefore help us uncover possible frame variants in texts, and at the same time give us a way to transform locative expressions into a map.