

A Formal Analysis and Systematization of Job Allocation in Multi-Robot Systems

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ABSTRACT: Multi-robot systems are the new dimensions for the Robotics Application environment in day today business; crucial intellectual aspects of multi-robot allotment mechanisms have untouched area for the exploration. To overcome this concern, we focus on the troubles of multi-robot Job allocation (MRJA). Most work on MRJA has been provisional and experimental, with much coordination planning having been proposed and validated in a proof-of-concept style, but infrequently analysed. With the target of bringing objective details to this important area of research, we deduce a formal study of MRJA problems. A domain-independent systemization of MRJA problems is given, and it is shown how many such problems can be viewed as occurrence of other, hardly viewed, optimization problems. We demonstrate how relevant theory from operations research and combinative breakthrough can be used for analysis and bigger understanding of existing platform to Job allocation, and to display how the equal theory can be used in the composite of new approaches.

KEYWORDS: Multi Robot, MRJA, Systemization.

I. INTRODUCTION

Over the past decade, an important shift of focus has occurred in the field of mobile robotics as researchers have begun to examine problems involving multiple, rather than single, robots. From early effort on loosely-coupled jobs such as uniform foraging (Matarić 1992) to more recent work on team coordination for robot soccer (Stone and Veloso 1999), the complexity of the multi-robot systems being considered has increased. This complexity has two primary sources better team sizes and greater heterogeneity of robots and odd jobs. Important achievements have been made along these axes; it is no longer enough to show, for example, a pair of robots observing targets or a large group of robots flocking as examples of coordinated robot behaviour. Today we intelligently expect to see increasingly larger robot teams engaged in concurrent and diverse jobs over extended periods of time.

MRJA(Multi-Robot Job Allocation)

As a result of the growing focal point on multi-robot systems, multi-robot coordination has received important attention. In particular, multi-robot job allocation (MRJA) has recently lift to elevation and become a leading research topic in its own right. As researchers design, build, and use mutual multi-robot systems, they invariably encounter the fundamental question: which robot should execute which job in order to cooperatively achieve the global goal? By “job”, we mean a sub goal that is

Necessary for achieving the overall objective of the system, and that can be achieved independently of other sub goals and from time to time in many cases make sense of partial or loud data (i.e., job). Jobs can be discrete (e.g. it delivers this package to room 101) or continuous (e.g., monitor the building entrance for intruders) and it can also diverge in a number of other ways, including time-scale, complexity, and specificity.

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Study of Existing Approaches

Presumably because it is the easiest case of MRJA, the ST–SR–IA problem has received the most thought from the research community. Having developed a proper framework in which to study to this MRJA problem, we can now apply it to an analysis of some of the key job allocation architectures from the literature. In this section, six approaches to the ST–SR–IA problem are analysed, focusing on the following three characteristics:

1. Computation necessities;
2. Communication necessities;
3. Solution quality.

These theoretical aspects of multi-robot synchronization mechanisms are highly important to their study, comparison, and objective evaluation, as the large scale and long term system behaviour is powerfully determined by the fundamental characteristics of the underlying algorithm(s). We can derive these characteristics for existing architectures by seeing them as solutions to the underlying utility optimization problems that we identified in our classification.

Anatomy of MRJA Problems

We propose anatomy of MRJA problems based on axes laid out below. Our goals here are twofold: (1) to show how various MRJA problems can be positioned in the resulting question space; (2) to explain how organizational theory relates to those problems and to propose solutions from the robotics literature. In some cases, it will be possible to construct provably optimal solutions, while in others only approximate solutions are available. There are also some difficult MRJA problems for which there do not currently exist good approximations. When designing a multi-robot system, it is essential to know what kind of job allocation problem is present in order to solve it in a good way.

We propose the following two axes for use in express to MRJA problems.

- **Single-job robots (SJ)** versus **multi-job robots (MJ)**: SJ means that each robot is capable of executing at most one job at a time, while MJ means that some robots can execute multiple jobs simultaneously.
- **Single-robot jobs (SR)** versus **multi-robot jobs (MR)**: SR means that each job requires exactly one Robot to achieve while MR means that some jobs can require multiple robots.

Here, we explain the procedure used in the analysis.

II. PROCEDURE

Computational requirements, or running time, are determined in the usual way, as the number of times that some dominant operation is repeated. For the MRJA domain, that operation is basically either a calculation or comparison of utility, and running time is declared as a function of m and n , the number of robots and jobs, respectively. Since modern robots have powerful processing capabilities on board and can easily work more tasks in parallel, in this analysis we assume that the computational load is evenly distributed over the robots, and state the running time as it is for each robot. For example, if each robot must select the job or task with the highest utility, then the running time is $O(n)$, because each robot performs n comparisons.

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III. RESULTS AND DISCUSSION

Six MRJA architectures that have been justified on either physical or simulated robots are tested. Three of the architectures determine the iterated assignment problems and the other three of them determine the on-line assignment problem. While there are a great many architectures in the literature, we have attempted to collect a set of approaches that is representative of the work to date of the iterated assignment architectures.

The first is ALLIANCE (Parker 1998), one of the earliest established approaches to MRJA. This behaviour based architecture allocates jobs by maintaining, for each robot, levels of edginess and concurrence concerning the available jobs. These motivational factors are combined to form, in effect, a utility estimate for each (robot and job) pair.

Another performance based architecture is BLE (Werger and Matarić 2001), which is a distributed version of the well-known Subsumption Architecture (Brooks 1986). As described in the robots find and broadcast to each other their utility estimates for all jobs; allocation is performed after each broadcast with the Greedy algorithm.

Another architecture that operate the Greedy algorithm is M+ (Botelho and Alami 1999), whose use of auctions defines the first market-based approach to MRJA (or at least the first that was motivated with economic ideas).

Reassignment of jobs is allowed in all three architectures, although the number of reassignments may change. For example, in BLE reassignment occurs essentially.

These results are particularly interesting because they suggest that there is some common methodology underlying many existing approaches to MRJA. This trend is difficult or impossible to determine from reading the technical papers describing the work, as each architecture is described in different terms, and validated in a different job domain. However, with the analysis described here, fundamental similarities of the various architectures become obvious. These similarities are encouraging because they suggest that, regardless of the details of the robots or jobs in use, the various authors are all studying a common, fundamental problem in autonomous co-ordination. As a corollary, there is now a formal grounding for the belief that these provisional architectures may have properties that allow them to be generalized and applied extensively.

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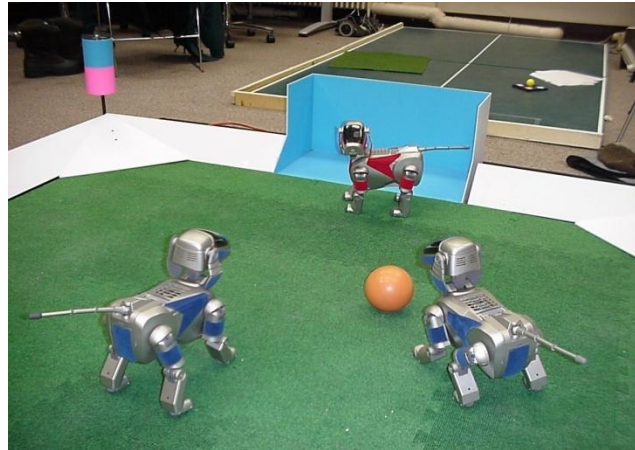
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REFERENCES

- 1- Chien, S., Barrett, A., Estlin, T., and Rabideau, G. 2000. A comparison of coordinated planning methods for cooperating rovers. Proceedings of Autonomous Agents, Barcelona, Spain, pp. 100–101.
- 2- M.J., and Sukhatme, G.S. 2002. Adaptive spatiotemporal organization in groups of robots. Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Lausanne, Switzerland, September 30–October 4, pp. 1044–1049.
- 3- Deneubourg, J.-L., Theraulaz, G., and Beckers, R. 1991. Swarm-made architectures. Proceedings of the European Conference on Artificial Life (ECAL), Paris, France, pp. 123–133.
- 4- Dertouzos, M.L. and Mok, A.K. 1983. Multiprocessor on-line scheduling of hard-real-time tasks. IEEE Transactions on Software Engineering 15(12):1497–1506.
- 5- Dias, M.B. and Stentz, A. 2001. A market approach to multi-robot coordination. Technical Report CMU-RI-TR-01-26, The Robotics Institute, Carnegie Mellon University, Pitts-burgh, PA.
- 6- Dias, M.B. and Stentz, A. 2002. Opportunistic optimization for market-based multi-robot control. Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Lausanne, Switzerland, September 30–October 4, pp. 2714–2720.
- 7- Donald, B., Jennings, J., and Rus, D. 1997. Information invariants for distributed manipulation. International Journal of Robotics Research 16(5):673–702.
- 8- Dudek, G., Jenkin, M., and Miliot, E. 2002. Taxonomy of multi-robot systems. Robot Teams: from Diversity to Polymorphism, T. Balch and L. Parker, editors. A.K. Peters, Natick, MA, pp. 3–22. Editors. AAAI Press, Menlo Park, CA, pp. 195–210.
- 9- B.P. and Matarić, M.J. 2002a. A market based formulation of sensor-actuator network coordination. Proceedings of the AAAI Spring Symposium on Intelligent Embedded and Distributed Systems, Palo Alto, CA, pp. 21–26.
- 10- Gerkey, B.P. and Matarić, M.J. 2002b. Sold!: Auction methods for multi-robot coordination. IEEE Transactions on Robotics and Automation 18(5):758–768.
- 11- Gerkey, B.P. and Matarić, M.J. 2003. Multi-Robot Task Allocation: Analysing the Complexity and Optimality of Key Architectures. Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Taipei, Tai-wan, pp. 3862–3868.
- 12- Guestrin, C., Koller, D., and Parr, R. 2001. Multi-agent planning with factored MDPs. Proceedings of Advances in Neural Information Processing Systems (NIPS), Vancouver, Canada, pp. 1523–1530.
- 13- Hoffman, K.L. and Padberg, M.W. 1993. Solving airline crew scheduling problems by branch-and-cut. Management Science 39(6):657–682.
- 14- Hoogeveen, J., van del Velde, S., and Veltman, B. 1994. Complexity of scheduling multiprocessor tasks with prespecified processor allocations. Discrete Applied Mathematics 55:259–
- 15- Emery, R., Sikorski, K., and Balch, T. 2002. Protocols for Collaboration, Coordination, and Dynamic Role Assignment in a Robot Team. Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Washington, DC, May 11–15, pp. 3008–3015.
- Fukuda, T., Nakagawa, S., Kawachi, Y., and Buss, M. 1988.