MURDOCH: Publish/Subscribe Task Allocation for Heterogeneous Agents

Brian P. Gerkey and **Maja J Matarić**
Computer Science Department
University of Southern California
941 West 37th Place, Mailcode 0781
Los Angeles, CA 90089-0781
bgerkey|mataric@cs.usc.edu, http://www-robotics.usc.edu/~agents/projects/pub-sub.html

Introduction In this paper, we describe a novel approach to the problem of dynamic task allocation among groups of heterogeneous agents. Specifically, we advocate the use of *publish/subscribe* messaging, a well-researched ((S+98)) and commercially proven ((TIB97)) message brokering paradigm that is readily applicable to distributed control. We present MURDOCH, an implemented publish-subscribe system, and explain how it can facilitate multi-robot coordination.

Publish/Subscribe Messaging At the heart of MURDOCH is an implementation of publish/subscribe messaging, which in turn depends on subject-based addressing. *Subject-based addressing* is an addressing scheme in which individual messages are addressed by content rather than destination. *Publish/subscribe messaging* is a messaging paradigm that uses *subject-based addressing* to divide a network into a loosely-coupled association of anonymous data producers and consumers. A data producer simply tags a message with a subject (or set of subjects) and "publishes" it onto the network; any data consumers who have "subscribed" to that subject (or set of subjects) will automatically receive the message. The goal of publish/subscribe messaging is to enable a loosely-coupled distributed system in which the data producers have no knowledge of the data consumers and vice versa.

Subject Namespace In our system, each robot subscribes to a set of subjects which represent its "capabilities". A mobile robot might subscribe to subjects such as `sonar`, `speech`, `camera`, `compass`, and `mobile`; a desktop PC, on the other hand, might subscribe to subjects such as `compute-server` and `mass-storage`. Thus, to reach all robots who have sonar sensors and cameras, one can publish a message to the subject `(sonar camera)`; only those machines with the specified capabilities will receive the message. In addition to those subjects which represent concrete robot capabilities, subjects can be more abstract representations of state information. For example, when a team of robots is engaged a cooperative box-pushing task, a robot's current perception of the box is extremely useful; thus domain-specific subjects such as `see-box` and `contacting-box` will be introduced and used to coordinate the robots' behavior throughout the progression of the task. These subscriptions can and do change over time. For example, with regard to our box-pushing task, which is a truly dynamic domain, individual sub-tasks will be periodically generated and published to subjects such as `contacting-box`; an agent's state with respect to this subscription will be constantly changing throughout the task, and sub-task assignments will reflect this.

Negotiation In MURDOCH, task allocation is performed by matching the set of resources needed to perform the task with agents who are capable of achieving it. An agent's capabilities at any point in time are described by the subjects to which it subscribes. So, in order to match a given task to capable agents, messages regarding the task should be tagged with a subject that describes the necessary resources. Resource requirements specified in this way (i.e. in the subject of a message) are "hard", in that they are not negotiable. Of course, more than one agent may be capable of performing a task and so there must be a method for selecting among a group of willing participants. We introduce metric functions, or simply *metrics* for this purpose. Along with a task description, a message concerning a task to be performed will also include a set of metrics which will be evaluated on each respondent, assigning it a "score", so that the system may (in a distributed fashion) select the agent best suited. In order to actually allocate the various pieces of a task, MURDOCH employs a simple, efficient, and decentralized negotiation protocol. The user phrases the task to be performed in terms of task components, each one described in terms of behavioral primitives, resource requirements, and eligibility metrics. MURDOCH then iterates through the components, and each agent claims those for which it most capable.

References

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