Realtime Dynamic Coalition Formation
Extended Abstract*

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Abstract

We briefly describe an implementation of a fully reactive, real-time approach to the problem of dynamic negotiation in the context of a real time distributed resource allocation problem involving multisensor tracking. We consider a number of variations and compare it with an auction-based approach. We also discuss similarities in the proposed solution with distributed region-growing approaches to image segmentation.

The distributed resource allocation problem

We have been investigating the issues surrounding the problem of dynamic negotiation in the context of a real time distributed resource allocation problem (DRAP) involving multisensor tracking. An example is shown in Figure 1. The figure depicts an array of nine doppler sensors. Each sensor has three sectors associated with it, labeled $\{1, 2, 3\}$. A sensor can turn on a sector and take both frequency and amplitude measurements to determine velocity and distance. A sensor can only have one sector on at a time, however. The farther away the target is from the sensor, the lower the quality of the measurement. At least two sensors are necessary for estimating the location of an object; three sensors are desirable for obtaining a good-quality estimate. Tasks can interact: for example, sectors require a 2 second warm-up time; therefore, an agent can benefit from tracking two targets in sequence because of the saved warm up time. Finally, two objects appearing in the same sector and at the same time cannot be discriminated.

Tasks can appear dynamically; the figure shows projected paths — based on initial localization, direction and velocity measurements — for two targets, $t1$ and $t2$. The problem is to allocate, in a distributed manner, a set of sensors along the paths of both targets. Each path is discretized into a set of space-time points along the path (indicated in the figure by small dark circles). We assume that agents are cooperative and work together to get the best possible measurements.

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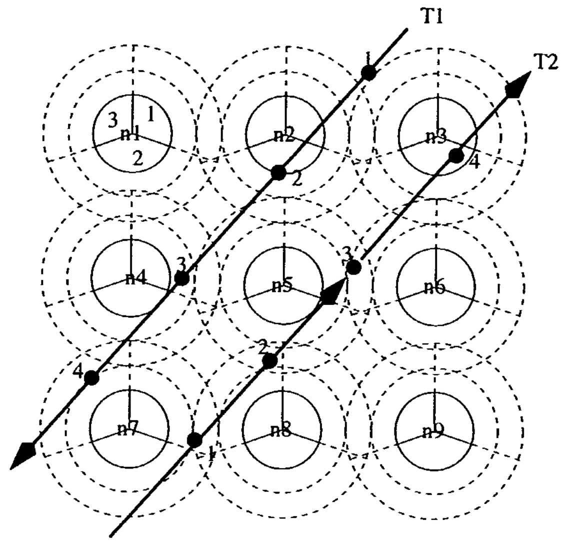

Figure 1: Multi-sensor tracking.

Candidate approaches to solving the DRAP

There are several approaches one could take to solving a DRAP. We describe one option in this section involving what we call task auctions (Ortiz *et al.* 2001). In this example, we assume that the projected paths have been computed — based on initial localization, direction and velocity measurements — for each of two targets, $T1$ and $T2$. The paths are shown as dark lines. The problem in this example is to allocate, in a distributed manner, a coalition of sensors along the paths of both targets. One way of implementing a task auction to allocate the sensors is to first assign nodes $n3$ and $n7$ each the role of auctioneer. Each would then initiate an auction for the respective tasks corresponding to an assignment of three sensors at each future time point — indicated in the figure by small dark circles — to nodes and relevant sectors.

Reactive coalition formation

The approach we are currently exploring, and which we will describe in detail in the full paper, is a purely reactive solution which we call, distributed realtime coalition formation

(DRTCF). In the auction-based approach described above, the coalitions (that is, the team of agents assigned to track a target at a particular space-time point) that are formed are formed as a result of an explicit negotiation between, in this case, an auctioneer and a set of candidate agents. In contrast, the DRTCF approach is based on the notion of an incremental formation of coalitions; the coalitions, in effect, emerge as the target moves. Our interest in such an approach is motivated in part by a desire to explore a continuum of solutions to the DRAP ranging from very fast solutions based on information strictly local to an agent to mechanisms, such as the auction-based approach, in which information is exchanged — in the case of the auction, in the form of local utilities — between nodes prior to allocation of resources. Our intuition is that the DRTCF approach is likely to be very fast, although it may be susceptible to task contention problems as the number of tasks grow. For such cases, we are exploring organization-centered approaches in which limited interactions are supported between higher level coalition leaders. We describe one such system called the Distributed Dispatch Manager (DDM) in (Yadgar, Kraus, & Ortiz 2002); the problem addressed in the DDM system differs slightly in that sensor agents can move. However, there is a close correspondence to the problem described in this paper since we can associate a sort of *virtual* movement with the agent coalitions.

Our proposal is illustrated in the finite state machine (FSM) shown in Figure 2. Essentially, each agent implements the behavior described by the FSM. All agents begin in detection mode, looking for objects in each of the three sectors. If no object is detected in the current sector then the agent pauses and switches sectors, repeating the detection activity. If a target is detected the track manager (TM), responsible for collecting measurements and fusing them, is informed and the agent transitions into tracking mode and waits for the track ID from the TM. If the ID is not received, the agent simply tries to inform the TM again. If the ID is received, the agent sends the latest data to the TM on that object. The agent continues tracking as long as the target is visible. Since all other agents are implementing the same behavior, any agent that detects the same target will send messages corresponding to the unique target ID to the TM. In this way, the coalitions are automatically formed and maintained as long as the target is visible.

In the full paper, we describe an implementation of this approach and variations and compare it with the auction-based mechanism. We also discuss similarities in the proposed DRTCF solution with distributed region-growing approaches to image segmentation. (Bader *et al.* 1995).

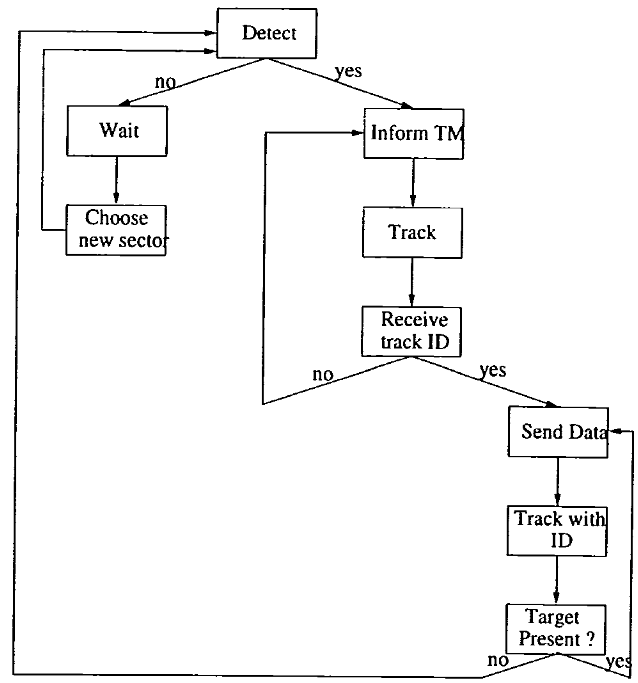

Figure 2: FSM describing individual agent behavior in the purely reactive coalition formation solution.

References

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