An empirical evaluation of reasoning about resource conflicts

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Abstract

It is important that intelligent agents are able to pursue multiple goals in parallel, in a rational manner. This work experimentally evaluates mechanisms presented previously which allow agents to detect and deal with situations where multiple goals conflict over limited resources. We describe X-JACK, our extension to JACK, a state of the art agent development toolkit. X-JACK incorporates an explicit structure for goals and the reasoning to detect and classify resource conflicts. We compare X-JACK to JACK experimentally, under a range of situations designed to stress test the conflict reasoning algorithms, as well as situations designed to be more similar to real applications. We find that the cost of the additional reasoning is small, even with large numbers of conflicts to reason about. The benefit however is noticeable, and is statistically significant, even when the amount of conflict and parallelism is relatively small.

Keywords Intelligent Agents, Resource conflicts.

1. Introduction

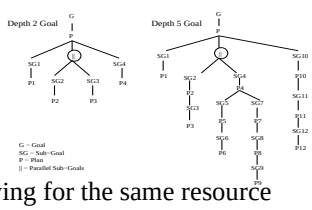
Agent programming and agent development platforms that facilitate building intelligent agents are becoming increasingly popular. In our earlier work [1, 2, 3] we have suggested ways to enable *intelligent agents* built using the popular Belief Desire Intention model (BDI) to reason about the interactions between goals that they are pursuing. Although it is clear that more reasoning allows an agent to behave more intelligently, the cost of that reasoning is also an issue. In this work we report on experimentation that we have done to ascertain both the costs and the benefits of reasoning about resource requirements as described in [3]. We find that the cost of the additional reasoning is small, even with large numbers of conflicts to reason about. The benefit however is noticeable and statistically significant, even when the amount of conflict is relatively small.

We review in this paper the data structures and algorithms for reasoning about conflicts between goals based on resource requirements, and then present our detailed investigation of differing environmental characteristics and the costs and benefits of incorporating this reasoning into an agent development toolkit. The specific toolkit we have chosen is JACK, a Java based state of the art agent development toolkit. We extend JACK (which we will call X-JACK - extended JACK) to incorporate an explicit structure for goals and the reasoning to detect and classify resource conflicts as outlined in [3]. We compare JACK and X-JACK in a range of situations, measuring the time taken for all the goals to complete (either successfully or by failure) and the number of goals successfully completed. Environmental variables which are controlled are the number of goals that compete for a particular resource (more competition results in greater conflict), the amount of resources available (less resources increases conflict), the number of goals that execute in parallel (more goals creates more interactions), and the depth of the goals in terms of sub-goals and plans (goals with greater depth will waste more resources if conflicts occur at a later stage).

In addition to indicating that this additional reasoning is not computationally expensive, our evaluation also provides an indication of the kind of domains for which goal-resource related reasoning is most important.

2. Experiments

In order to compare the behaviour of X-JACK with JACK we set up abstract scenarios, varying the aspects described in section one above in order to test both costs and benefits. The experiments used two different structures of top level goals, as shown in the figure to the right. These goal structures captured both differences in plan numbers and differences in goal depth. The percentage of goals vying for the same resource and the total availability of resources was varied. The run-



time for a single goal of depth 2 was approximately 62 seconds, and for depth 5 was 162 seconds. The amount of parallelism was varied by changing the rates at which goals were added into the system. Each experiment ran 50 goals in total, and was run 10 times, with the ordering of goals chosen randomly. All experiments were run on an Intel Pentium 4 dedicated PC under linux 7.2 operating system. The speed of the processor was 1.7 GHz and 512 MBytes of RAM were available. The scenarios were developed in JACK version 4.1 and Java version 1.4.2. In the following experiments the time recorded is the actual clock time taken for the experiments to complete. The experiments can be grouped into 4 different explorations: Costs and benefits at differing levels of resource availability, with a) high levels of interaction between goals and b) normal/lower levels of interaction between goals. c) Analysis of cost of conflict reasoning. d) Exploration of situations with possible conflict and random failure. Due to lack of space we do not report here on the 4th set of experiments, as there are complex nuances which require detailed explanation. They will be presented in a future technical report. The results for the first three are summarised below.

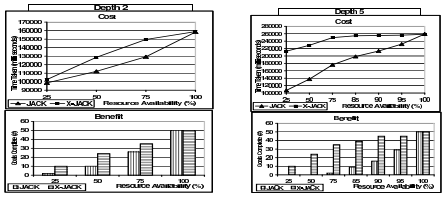


Figure 1. High levels of goal interaction.

Figure 1 shows the results for high levels of goal interaction. In summary, the lower the resource levels, the higher the number of goals running in parallel and the greater the amount of plans required to complete by each goal, the greater the benefit is in using X-JACK. However even in situations of least benefit (except when there is no conflict), X-JACK shows small yet significant benefit over JACK.

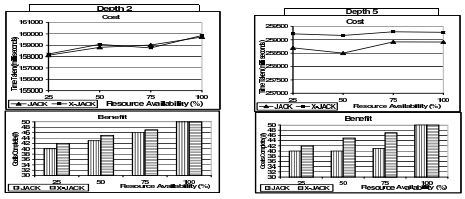
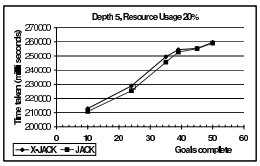


Figure 2. Lower levels of goal interaction

Figure 2 shows the results when the level of interaction is more natural in applications. Even with low levels of interaction the benefits are significant with a minimal cost.

In order to determine the approximate cost of the reasoning methods, we re-ran the experiments we did for high levels of goal interaction ensuring that the same goals completed for X-JACK also completed for JACK. This would give us comparable timings for the same number of goals to run without the additional reasoning. The results are shown in the figure to the right. When there is no conflict the reasoning overhead is insignificant. Whilst there is a difference in times when there is conflict in the system, the difference is very low. For in the situation where there was most conflict 10 goals complete in X-JACK and 0 in JACK. The difference in times at this point is less than 1.8 seconds. An overhead of less than 1.8 seconds to complete 10 goals as opposed to none is certainly very acceptable.



3. Conclusion

In this paper we have described experimental work evaluating the costs and benefits of managing resource conflicts for a single agent with multiple goals. The ability to pursue multiple goals is one of the hallmarks of an intelligent agent, and it is important that this is able to be done in a rational way. We presented X-JACK, an extension to JACK which incorporated the concept of goals and reasoning algorithms about goal resource conflicts which we presented in previous work. We described an experimental setting for evaluating a system that allows reasoning about resource conflicts (such as X-JACK) against one that does not (such as JACK). Results show clearly that even under extreme circumstances of very high levels of goal interaction and conflict the cost is not excessive and the benefit of the system is evident even when there is little interaction.

References

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