Comparison of Performance for CNP and eCNP in a Warehouse Scenario with Different Idling Zone Distributions

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Abstract

We will compare the performance of different multi-agent systems in a warehouse scenario in which agents are collecting goods to complete orders. In our previous work, we demonstrated a simulation to examine the effect of the idling zone count and distribution strategies. In this article, we will use the best and worst cases from our previous work and analyze how CNP and eCNP methods affect their performances.

1 Introduction

Multi-agent systems are widely used in many industries to solve complex problems. Warehouse management is also a field in that multi-agent systems could be used in order to increase efficiency. However, there are some points that are often discussed in the field to optimize the system[1]. In our previous work[2], we conducted some experiments with different idling zone distribution strategies, different agent counts, and different idling zone counts based on their percentage of the selected agent count. The best performance was achieved with the random border distribution. The nearest border distribution performed the worst in most of the other experiments. In our previous setup, agents did not have any communication with each other and each completed the assigned tasks by themselves.

By segmenting tasks and introducing a (sub)task allocation algorithms, CNP and eCNP improve the collaboration between agents, thus increasing the overall performance. In the following sections, we will examine how much these methods can improve our best results from the previous work compared to the worst-performing strategy.

2 Methods

We model a warehouse scenario where tasks are assigned to agents by different methods such as CNP, eCNP and without using any kind of CNP (this will be mentioned as NoCNP). Additionally, idling zones are distributed based on different strategies such as random and nearest border distributions.

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2.1 Idling Zone Distribution Methods

With a random distribution strategy, idling zones are distributed randomly on a free spot in the warehouse. The nearest border distribution strategy denotes that only the borders, that are closest to the drop-off zones, are used. In case these borders are filled, the allocation of the idling zones takes place the same as random distribution. In figures 1 and 2, the utilized idling zone distribution strategies are introduced.

Figure 1: Random Distribution of the Idling Zones[2]

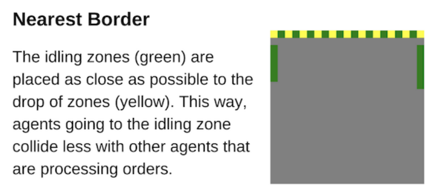

Figure 2: Nearest Border Distribution of the Idling Zones[2]

2.2 Task Allocation Methods

The NoCNP is the simple task allocation algorithm used in the previous work. Tasks are assigned to free agents and they collect the goods of a task one by one.

The implementation of the CNP (Contract-Net-Protocol) method follows the idea of optimizing the agent's path to the first good of a given order. Due to this optimization, we assume to produce fewer collisions in the warehouse setup and generally decrease the time to pick up the first good of an order. Once an order becomes available to the system we make it available for bidding. All free agents make proposals by calculating the hamming distance to the first good of the new order. Out of all these proposals, the minimum bid is selected and the corresponding agents get assigned the task to deliver the sequence of goods. If no agent is available to make a bid we wait with the bidding process until at least one agent can process the order.
We initially also introduced a counter for the bidding process to allow bidding for the same order over multiple time steps and collect the bids until a given deadline but we observed decreased performance due to this procedure.

The eCNP method extends the CNP method by redistributing partial sequences of goods. We have implemented a reporting system for global messages which we utilize to reallocate an already processing order to free agents in order to maximize efficiency. Agents post messages to the reporting system which we internally also use to count the number of completed orders. We propose to inform the system about dropped and picked-up goods by each agent. We can broadcast these messages to free agents and initiate new bidding rounds based on them.
The eCNP method directly uses the CNP method to initially assign orders to agents following the procedure described before. Once an agent picks up a good of an order we split the given order into two parts and make the second part available for bidding again. The first part will be continued to be processed by the agent who initiated the rebidding. If no other agent is available to bid for the second part we assign the second part to the initiating agent as well which implies that we have no difference in behavior to the CNP version if the system is utilizing 100% of the available resources at any given time. Because that's normally not the case we are trying to redistribute the workload to free agents to achieve increased efficiency. We have limited the splitting of the order to only two parts because we observed in earlier experiments that slicing the order into smaller pieces introduces more collisions due to the nature of the bidding procedure. The bidding process usually prefers agents centered in the warehouse which leads to many collisions and stuck agents because the center gets crowded. We also observe this behavior in the current version, though to a smaller extent, which is explained in detail in the results of our experiments. Further, we propose that rebidding is only initiated if a certain number of agents are available to participate in the bidding process. In the mentioned earlier experiments we saw a massive decline in performance by allowing the rebidding without this constraint. By requiring more participants for the bidding process we increase the chances of finding a close agent. This way we were able to cancel the effects of producing more collisions due to more moving agents in the warehouse.

3 Experiments and Results

We ran different experiments with the methods explained in the previous section. In this section, the results are introduced and discussed in the next section.

Two different square-shaped warehouse setups were used 21x21 and 41x41, respectively. For the 21x21 warehouse setup, we have conducted experiments with 20, 50, 100, and 200 agents. As the warehouse scales from 21x21 to 41x41, the scaling factor of 3,81 was used for the 41x41 warehouse setup. This means that 76, 190, 381, and 762 agents were used. The idling zone count was set to 25% of the agent count.

3.1 Constraints

Each agent is capable of moving horizontally and vertically. Orders are sequences of coordinates in the warehouse, there are no quantities or titles for goods for simplification. Each agent can only carry one order at a time. It doesn't matter to which drop-off zone a good is delivered. As the warehouse considered as shown in figure 3, goods in the warehouse do not cause any collision.

Figure 3: Warehouse Example[3]

3.2 Results

The overall results are shown below in Figures 4 and 5. As a performance indicator, the number of completed orders is used to compare the results. The best results were achieved with the 100 and 381 agents, respectively. For the smaller warehouse, the eCNP method performed the best with randomly distributed idling zones. When the nearest border distribution was used, the best results were achieved with NoCNP.

For the bigger warehouse, CNP and NoCNP methods yielded very similar results and performed the best with randomly distributed idling zones. When we used the nearest border distribution strategy, the best result was reached with the NoCNP method.

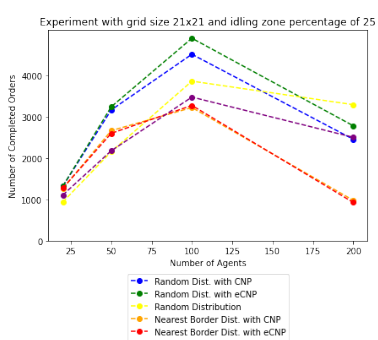

Figure 4: Experiment Results for the 21x21 Warehouse Setup

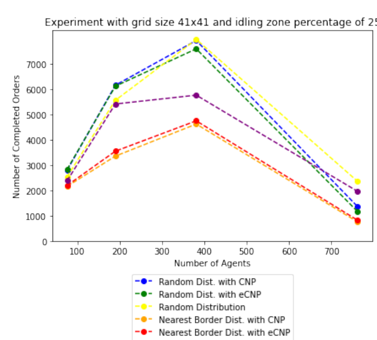

Figure 5: Experiment Results for the 41x41 Warehouse Setup

In addition to the performance comparison, in figures 6-9, the counts of the collisions are shared. They are grouped based on the idling zone distribution strategy used with respect to the warehouse setup used.

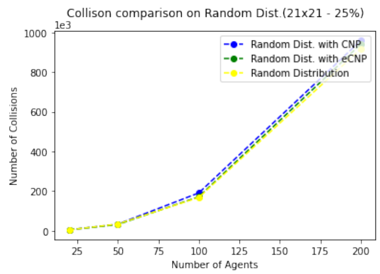

Figure 6: Collision Counts of Experiments with Random Distribution for 21x21 Warehouse Setup

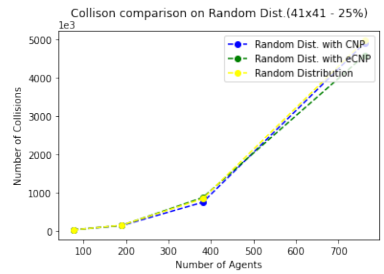

Figure 8: Collision Counts of Experiments with Nearest Border Dist. for 21x21 Warehouse Setup

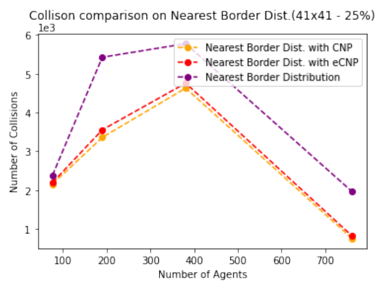

Figure 7: Collision Counts of Experiments with Nearest Border Dist. for 41x41 Warehouse Setup

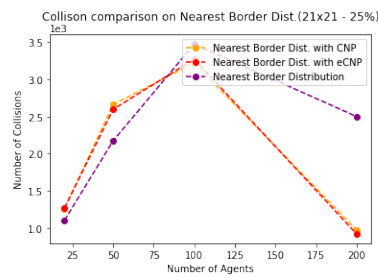

Figure 9: Collision Counts of Experiments with Random Distribution for 41x41 Warehouse Setup

The number of collisions that occurred does not vary much for the experiments with random distribution and for both warehouse setups. However, when the nearest border distribution was used, the CNP and eCNP methods reduced the collision count in most of the experiments.

4 Discussion

In the previous work and during the experiments presented here, we observed a correlation between the number of collisions and tasks completed after a threshold on collisions is exceeded. Experiments with the random distribution strategy showed us that the CNP and eCNP slightly improved the performance. The results reached on the experiments with nearest border distribution, however, yielded a different outcome. In figures 5 and 7, we observed that the number of collisions decreased significantly with CNP methods, and on the other hand we received worse results in comparison to the NoCNP method.

This situation has been investigated, and we suppose that the problem with the nearest border distribution mentioned in the previous work was causing this. With the nearest border distribution, some agents got stuck at the top lane and therefore the strategy performed the worse. The experiments with CNP methods also did not change this behavior. Thus, the agents that got stuck at the top were not assigned to any task, as their position is the furthest place to the goods. As a result of their suspension, there were fewer agents to handle the tasks and create collisions.

5 Summary

In this paper, we examined and presented the effect of the task allocation algorithms, namely CNP and eCNP methods, on our previous warehouse scenario. The scenario was simulated in two different warehouse setups and with two different idling zone distribution strategies. As the CNP and eCNP improved the performance of our previous work, they caused worse performance outcomes for the nearest border distribution strategy in comparison to our previous work. This unexpected behavior occurred due to the agents getting stuck at the top lane and not being assigned to any task as mentioned earlier on the poster.

References

[1]Leitão, P. (2013). Multi-agent systems in industry: current trends and future challenges. In J. Kelemen, J. Romportl, and E. Zackova (Eds.), Beyond Artificial Intelligence: Contemplations, Expectations, Applications (pp. 197–201).

[2]https://isis.tu-berlin.de/pluginfile.php/2312840/assignsubmission_file/submission_files/2242104/Comparison%20of%20the%20reactive%20agents%20performance%20based%20on%20idling%20zone%20in%20a%20warehouse%282%29.png?forcedownload=1

[3]https://www.fortna.com/wp-content/uploads/2021/01/Warehouse-Robots-image-17.jpg