Shift Scheduling using a Multi-agent System over Contract Net Interaction Protocol

Gustavo Flores
Pontifical Catholic University of Rio Grande do Sul (PUCRS)
Porto Alegre, Brazil
gustavo.pereira87@edu.pucrs.br

***Abstract*—Shift scheduling of workforce is a economic relevant topic for many companies, and still a relevant challenge considering different types of work contract, flexible hours and employee satisfaction. This paper presents a solution for the problem of shift scheduling using a Multi-agent System with Contract Net Protocol communication. We tested our system in a scenario of multiple staff agents, in three different roles, accepting or refusing proposals of shifts initiated by a manager agent.**

***Index Terms*—autonomous agents, bdi, shift scheduling, workforce management**

I. Introduction

Labor cost is a concern in companies, being a major cost component. Thus, a personnel scheduling could be helpful if it is able to reduce this cost by some extent. Many solutions to this problem have been proposed over the years, methods involving linear programming, goal programming and artificial intelligence [1].

We propose a methodology based on Multi-agent Systems (MAS) with Contract Net Protocol communication, in which a manager agent starts a process of proposal bidding for work shifts and the other participants are required to issue a propose or refuse that call for each shift and workday based on their restrictions of availability.

Considering a full week of shifts, we conducted a simulation for 29 agents (one manager and 28 staff personnel), where each member of staff could apply to one of three different roles. All protocols ended successfully, with agents accepting or refusing the proposals considering their initial availability. Our methodology was able to plan over the entire week horizon, allocating personnel for each shift initially considered. Despite that positive outcome, we encountered limitations on our implementation regarding the exact number of required personnel for each role proposed.

II. Background

Baker [2] classifies personnel scheduling in three groups: shift scheduling, days off scheduling and tour scheduling — a combination of the first two types. In shift scheduling, we plan over a horizon of seven days with more than one shift a day. Allocations are independent for each shift and its staff requirements [1]. Contracts can be full-time, part-time or flexible, and account for employee preference for a specific shift when creating work schedules.

III. Methodology

A. FIPA Contract Net Protocol

In FIPA Contract Net Protocol[1] [3], we have two agent roles. A initiator, that defines the task to be performed, and other agents known as the participants — the ones that perform the task. The initiator starts sending a call for proposals (*cfp*) to the other agents (Figure 1), which respond with a proposal if they are willing to perform the task, or a refusal otherwise.

The initiator then deliberates on which proposals to accept based on conditions regarding the execution of the task. One, many or no agent may be chosen to perform the task. Those agents that have their proposals accepted receive a accept-proposal act. Then the participant must perform the task, informing the initiator with a inform-done act once the task has been completed — a failure must be sent in case the participant fails to achieve the proposed task.

The inform-done act marks the completion of that protocol. The initiator has to complete each protocol before issuing a new call for proposals.

B. Agents

We implemented a MAS, where each agent behaves independently regarding their beliefs, desires and intentions [4]. Each intention of an agent has a plan that defines a set of actions and conditions for that intention to be achieved, and each belief describes a perception of the agent regarding itself, the system or other agents.

Our solution followed a similar implementation[2] of Contract Net Protocol using the BDI (*Beliefs-Desires-Intentions*) architecture and Jason interpreter. We defined three agent roles in the MAS:

1) Initiator: a manager with the intention of scheduling each shift of the week with the desired personnel for three roles: *seller, cashier* and *stock*. This agent is responsible for issuing a call for proposals for a specific day and shift (e.g., "Monday, Day Shift"), and has beliefs for days and shifts desired to be scheduled, and the number of personnel desired for each position.

The initiator expects to receive beliefs of proposal and refusal from other participants for each solicitation. When the

[1]http://www.fipa.org/specs/fipa00029/SC00029H.html
[2]https://github.com/cleberjamaral/tp_cnp

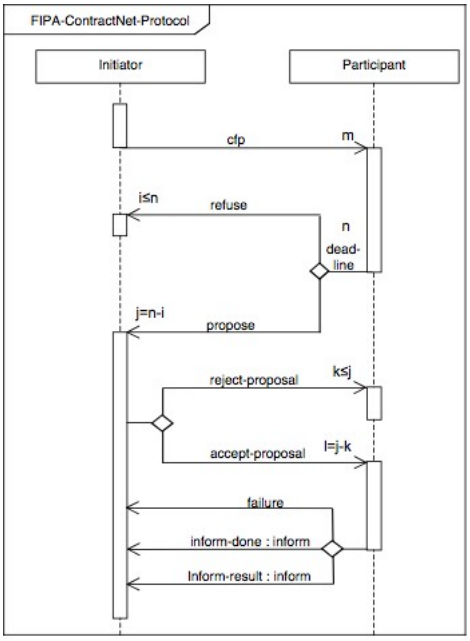

Fig. 1. FIPA Contract Net Protocol.

protocol is completed, the manager also receives a information of done as a belief.

2) Participants: participants have beliefs regarding their role (*seller, cashier* or *stock*) and the days and shifts they are available to work. Each participant receive the call and respond with a proposal if it is available for assuming that day and shift.

3) Controller: is responsible for declaring the end of the scheduling and stopping the MAS.

IV. Results and Discussions

Our MAS was tested in a scenario where we have available 16 sellers, 8 cashiers and 4 stock personnel. Participants had restrictions in their availability, having at least two days off. In this scenario, for each shift the manager agent selected 4 participants for the role of seller, one for cashier and one for stock. The results of the scheduling can be seen in Figure 2.

The scheduling ended successfully for each day and shift planned, and the Contract Net Protocol was successful managing the proposals and refusals, and also informing when the protocol was done. Despite that, we had limitations restricting the selection for the right number of wanted of personnel: some roles had more participants selected than the number informed by the manager, and when provided with less-than-optimal available participants (a case of scheduling failure), our system ended with status of success.

V. Conclusion

In this paper, we implemented a Multi-agent System with Contract Net Protocol communication for resolving the task of shift scheduling of personnel. Our tested scenario shown interesting results that could be developed even further to address the limitations encountered. A future work on the

informDone("Friday","Day Shift")[source(cashier1),source(cashier5),source(seller1),source(seller2),source(seller3),source(seller4),source(stock1)]"
informDone("Friday","Night Shift")[source(cashier3),source(cashier7),source(seller10),source(seller11),source(seller12),source(seller9),source(stock3)]"
informDone("Monday","Day Shift")[source(cashier2),source(cashier6),source(seller5),source(seller6),source(seller7),source(seller8),source(stock2)]"
informDone("Monday","Night Shift")[source(cashier4),source(cashier8),source(seller13),source(seller14),source(seller15),source(seller16)]"
informDone("Saturday","Day Shift")[source(cashier1),source(cashier5),source(seller1),source(seller2),source(seller3),source(seller4),source(stock1)]"
informDone("Saturday","Night Shift")[source(cashier3),source(cashier7),source(seller10),source(seller11),source(seller12),source(seller9),source(stock3)]"
informDone("Sunday","Day Shift")[source(cashier2),source(cashier6),source(seller5),source(seller6),source(seller7),source(seller8),source(stock2)]"
informDone("Sunday","Night Shift")[source(cashier4),source(cashier8),source(seller13),source(seller14),source(seller15),source(seller16)]"
informDone("Thursday","Day Shift")[source(cashier1),source(cashier2),source(seller3),source(seller4),source(seller7),source(stock1),source(stock2)]"
informDone("Thursday","Night Shift")[source(cashier3),source(cashier4),source(seller10),source(seller11),source(seller12),source(seller13),source(stock3)]"
informDone("Tuesday","Day Shift")[source(cashier1),source(cashier2),source(seller1),source(seller2),source(seller4),source(seller6),source(stock2)]"
informDone("Tuesday","Night Shift")[source(cashier7),source(cashier8),source(seller11),source(seller12),source(seller13),source(seller14),source(stock3)]"
informDone("Wednesday","Day Shift")[source(cashier1),source(cashier2),source(seller1),source(seller5),source(seller6),source(seller8),source(stock1)]"
informDone("Wednesday","Night Shift")[source(cashier7),source(cashier8),source(seller12),source(seller15),source(seller16),source(seller9),source(stock3)]"

Fig. 2. Result of scheduling scenario.

subject could extend the ability of our MAS to minimize the workforce needed to fulfill the required roles defined by the initiator while incorporating the optimization of days off for each participant. Our system would also benefit from a robust implementation of failure and cancellation of proposals.

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