Monitoring and controlling the execution of the sea cargo port operation's schedule based on multi-agent technologies

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Abstract. The seaport is a complex facility, the work of which is affected by many external factors. Its efficiency is provided by the competent scheduling of the operations performed. The previously developed automated system allowing to generate the optimal cargo handling schedule in the sea cargo port and considering the dynamic effect of external factors on its efficient operation requires the controlling the execution of planned operations and the strict compliance with the schedule. In this paper, we review the multi-agent approach providing the work performance control according to the schedule. In case of unforeseen changes in external factors rendering impossible the existing plan execution (vessel delay, equipment breakdown), agents track the source of the problem and inform the dispatcher about the need for adjusting the operations' schedule.

1.Introduction

The seaport operation is a complex and multifactor process, with its efficiency depending on the correctly generated plan (schedule) of work. Otherwise, the inevitable interruptions and downtimes may lead to the large losses of finances and time. To solve this problem, it is necessary to create a schedule ensuring the maximum efficiency of the port's operation, with avoiding delays, inconsistencies in the tonnage of ships and vehicles, with allowance for the resources of vessels and the order conditions [7].

In this article "schedule of activities" in the seaport means the dynamically corrected schedule of stevedoring and logistics operations that are necessary for cargo handling in the port. The requirements for maximum reduction of work stoppage in the port's operation put severe restrictions upon the schedule generation [2]. Since modern production facilities are proceeding from a centralized location scheme to a distributed one, registering the effect of external factors in real time is fundamental for generating a preliminary work schedule for the facility under consideration. The use of multi-agent technologies not only provides these requirements, but also allows to solve complex problems with a large number of variables - by breaking it into simpler tasks. Software entities (agents) corresponding to the controlled objects (vessels, port infrastructural units, transport units) mutually exchange information and provide their current status info to the scheduling module. In the scheduling module, based on the received data, an efficient schedule for the port operation is generated [8].

Thus, an automated system has been developed, able to generate the optimal stevedoring schedule of in the sea cargo port, allowing for the dynamic effect of external factors upon its efficient operation. The system employs a multi-agent approach to scheduling. It is supposed to use the data received from different agents and corrected during the interaction of such agents, in order to generate a port operation schedule.

The purpose of this article is to describe the interaction of agents after their receiving a schedule from the scheduling module, with its operation scheme presented in [9].

2. Agents interaction's scheme

The organization of the sea cargo port's operation implies not only the generation of the schedule, but also the subsequent control of its implementation and, if necessary, a certain modification. It is expedient to organize the control over the schedule execution at the level of the agents whose models were described in [10].

An essential addition to the previously described agents is the "Terminal" agent model. It is an agent that links other agents, and it is also an aggregator of information that interacts with the scheduling module, if necessary.

The "Terminal" agent model can be presented as:

$$Ter\left(at, zht, \langle kr\rangle, \langle zt\rangle, \langle zw\rangle, deepness\right),$$

where at — a parameter that indicates the availability of unloading by road, takes the values {0 - no, 1 – yes}, zht — a parameter that indicates the availability of unloading by rail, takes the values {0 - no, 1 - yes}, $\langle kr\rangle$ — a group of parameters indicating whether a particular crane will be able to load and which cranes belong to the terminal, $\langle zt\rangle$ — a group of parameters indicating whether a particular fuel tanker will be able to refuel with fuel and to which terminal it applies, $\langle zw\rangle$ — a group of parameters indicating whether a particular water tanker can be charged with water and to which terminal it belongs, deepness – possible draft. After receiving timetable data, that contains information on the arrival time of certain vessels, the agent «Terminal» begins to interrogate other agents, such as vessels that are due to arrive at the unloading at this terminal, as well as the agents of the port structures, for more information. The interaction scheme of agents in this situation is presented in Figure 1.

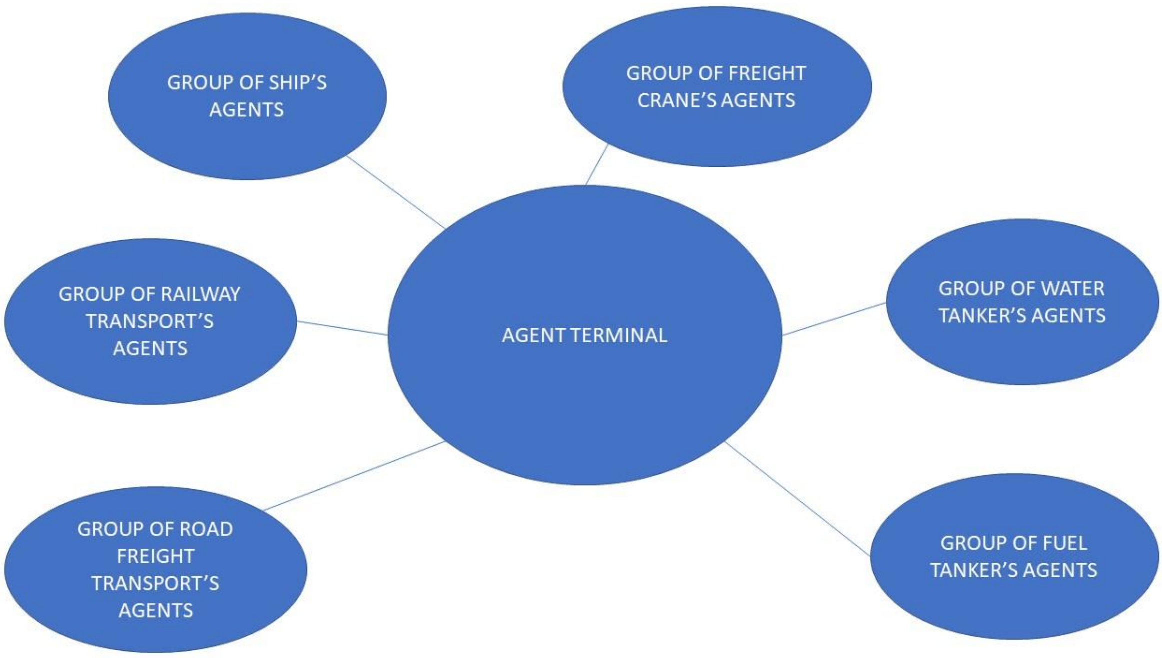

Figure 1. Scheme of agent's interaction after receiving the schedule from the scheduling module.

2.1. The interaction function of the «Terminal» and «Ship» agents

$$F_1 : (\mathrm{Ter}, \mathrm{S}) \to (\mathrm{Ter}, t, \mathrm{add\_inf}),$$

where Ter — agent «Terminal», S – agent «Ship», t — expected real time of arrival, $\mathrm{add\_inf}$ — additional information about the vessel (the agent «Terminal» checks the conformity of the actions to be performed with the vessel upon its arrival and actions described in the transferred timetable).

Using the function F_1 agent «Terminal» interrogates the agent «Ship» about its time of arrival.

If the vessel arrives on time, then the terminal will interrogate the port structures agents for their employment during the arrival of the vessel at the terminal. It also receives information about the operations that must be carried out with the ship as soon as it arrives at the terminal. If the ship is late, the terminal agent sends an alert to the scheduling module, where the procedure of adjusting the schedule with minimal losses starts.

2.2. The interaction function of the "Terminal" and "Freight crane» agent:

$$F_2 : (\mathrm{Ter}, \mathrm{kr}) \to (\mathrm{Ter}, \mathrm{a}, \mathrm{b}),$$

where Ter — agent «Terminal», kr – agent «Freight crane», a — the possibility of a port crane to work at the terminal during the arrival of the vessel, b — the possibility of this crane to load / unload this type of cargo.

Using the function F_2 the agent «Terminal» interrogates the agent «Freight crane» about the possibility of its work during the arrival of the vessel (is it busy with other operations) and if is it possible to unload the incoming cargo by this crane.

2.3. Function of interaction of the "Terminal" and the «Fuel tanker» agents

$$F_3 : (\mathrm{Ter}, \mathrm{zt}) \to (\mathrm{Ter}, \mathrm{c}, \mathrm{d}),$$

where Ter — agent «Terminal», zt – agent «Fuel tanker», c — the possibility of fuel refueling at the terminal during the arrival of the vessel, d — possibility to refuel this type of vessel.

Using the function F_3 the agent «Terminal» interrogates the «Fuel tanker» agent, whether it will be able to stay on this terminal during the arrival of the vessel and whether it will be able to fuel it.

The interaction between the agent «Terminal» and the agent «Water tanker» can be represented similarly.

2.4. Function of interaction of the «Terminal» and the «Road freight transport» agents

$$F_4 : (\mathrm{Ter}, \mathrm{at}) \to (\mathrm{Ter}, \mathrm{e}, \mathrm{f})$$

where Ter — agent «Terminal», at – agent «Road freight transport», e — parameter employment of the agent «Road freight transport» during the arrival of the goods, f — the possibility of unloading this type of cargo by this type of motor transport.

Using the function F_4 the agent «Terminal» interrogates the agent «Road freight transport» about the possibility of approaching this terminal during the arrival of the vessel and unloading this type of cargo.

Similarly, the interaction between the agent «Terminal» and the agent «Rail freight transport» can be represented, if the terminal has the possibility of using the railway transport.

After the agent «Terminal» receives all the necessary information confirming the readiness of the agents to work according to the received schedule, the agent «Terminal» sends confirmation to the scheduling module demonstrating the readiness of the schedule according to the received scheme. Then comes the next stage of agents' interaction. At this stage, the interaction of agents can be represented in accordance with Figure2.

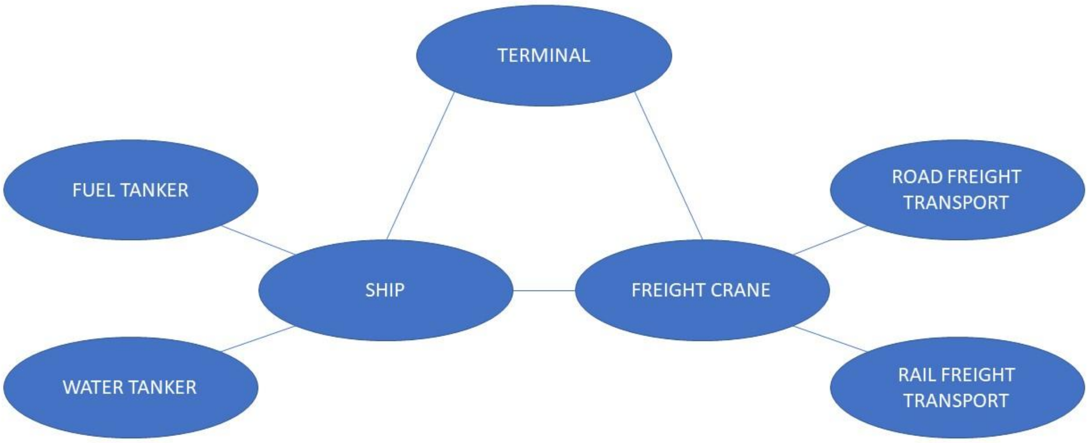

Figure 2. Scheme of interaction between agents after the approval of the schedule by all agents.

2.5 The interaction function of the «Terminal» and the «Ship» agents

$$F_5 : (\mathrm{Ter}, \mathrm{S}) \rightarrow (\mathrm{S}, \langle zt \rangle, \langle zw \rangle),$$

where Ter — agent «Terminal», S – agent «Ship», $\langle zt \rangle$ — a lot of refuelers available for refueling this type of vessel, which were previously interviewed by the agent «Terminal», $\langle zw \rangle$ — a lot of water tankers available for refueling this type of vessel, which were previously interviewed by the agent «Terminal».

Using the function F_5 the agent "Ship" gets information about which fuel and water tankers will arrive to work with this vessel during its parking at the terminal exactly.

2.6. The interaction function of the «Terminal» and «Freight crane» agents

$$F_6 : (\mathrm{Ter}, \mathrm{kr}) \rightarrow (\mathrm{kr}, \langle \mathrm{at} \rangle, \langle \mathrm{zht} \rangle),$$

where Ter — agent «Terminal», kr – agent «Freight crane», $\langle at \rangle$ — a lot of road freight transport available for loading / unloading of this vessel, which were previously interviewed by the agent «Terminal» $\langle zht \rangle$ — a lot of railway freight transport available for unloading / loading, which were previously interviewed by the agent «Terminal».

Using the function F_6 the agent «Freight crane» receives information about which particular cargo transport units are available for loading / unloading this vessel during its parking at the terminal.

2.7. The interaction function of the «Ship» and the «Freight Crane» agents

$$F_7 : (\mathrm{S}, \langle kr \rangle) \rightarrow (\mathrm{S}, \langle kr \rangle),$$

where S — agent «Ship», kr – agent «Freight crane».

Using the function F_7 the agent «Ship» gets information about exactly which cargo cranes will participate in unloading this vessel on this terminal.

2.8. The interaction function of the «Ship» and the «Fuel tanker» agents

$$F_8 : (\mathrm{S}, \mathrm{zt}) \to (\mathrm{S}, t),$$

where S — agent «Ship», zt – agent «Fuel tanker», t — time of arrival of the fuel tanker to the ship.

Using the function F_8 the agent «Ship» carries out a call to the fuel tanker, information about which was previously transferred from the agent "Terminal". In response to the call, the agent "Fuel tanker" reports the exact time of arrival and the beginning of the refueling of the vessel.

Similarly, the interaction between the agent «Ship» and the agent «Water tanker» can be represented.

2.9. Interaction function of the «Freight Crane» and «Road freight transport» agents

$$F_9 : (\mathrm{kr}, \mathrm{at}) \to (\mathrm{kr}, t),$$

where kr — agent «Freight crane», at – agent «Road freight transport», t — time of arrival of road freight transport to the place of work of the cargo crane.

Using the function F_9 the agent «Freight crane» carries out a call for road freight transport, information about which was previously transferred from the agent «Terminal». In response to the call, the agent « Freight Crane» reports the exact time of arrival to the workplace of the cargo crane.

Similarly, the interaction between the agent «Freight Crane» and the agent «Rail freight transport» can be represented.

After completion of loading / unloading of the vessel, the agent «Ship» informs the agent «Terminal» and the scheduling module about the completion of all operations.

3. Conclusion

The efficient schedule generation for cargo handling in a seaport with using multi-agent technologies allows the port to operate in the most efficient manner, due to considering the necessary criteria for this. At the same time, even the most correctly generated schedule is not the solution to all operational problems of the sea cargo port, if the execution of such schedule is not controlled by anyone. This article describes one of the possible approaches to such control, based on multi-agent technologies [6]. The agent interaction functions presented in this article describe the joint work of the agents after they receive the schedule from the scheduling module and allow to perform the full vessel service cycle at the terminal in the sea cargo port [4].

Future plans, according to the current research, are devoted to the evaluation of the algorithms on the real datasets.

Currently, methods and technologies for the use of decentralized distributed registers are being actively developed that are linked to the blockchains - the technologies of blockades and "smart contracts". Such technologies can be used with a high degree of efficiency in logistics operations, including multi-stage transfer links when processing transaction documents for shipment, multiple transshipment (transshipment) of cargo from one type of vehicle to another and cargo delivery to the final destination and the recipient. At the same time, the use of the appropriate blockchain platform, including mechanisms for smart contract generation, guarantees the precision and confidentiality of transactions [1]. Multi-agent technologies, in turn, will ensure effective monitoring of the goods traffic in such a large economic organization as a modern seaport or airport, and will control the execution of smart contract items at all key (critical) points of logistics operations.

Thus, the authors propose to link the methods and technologies of generating a dynamically corrected logistics schedule based on genetic algorithms, with multi-agent technologies for continuous monitoring of current situation and with control of performance and smart contract technology based on distributed registers for a complex multi-stage precise documentation support of the work performed.

4. References

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