Application of Multi-Agent Approach at Development of the Planning System of Oil Products Supply of Gas Stations Network

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Abstract

The results of application of multi-agent technologies have already proved themselves in various types of logistics: procurement, transport, sales, production, warehousing, information. The analysis of decision support systems (DSS) did not allow to identify in the open sources of specialized DSS planning of fuel transportation. Therefore, problem-oriented systems used in logistics, such as AnyLogic, ARIS, Business Studio, G2, Magenta, BPsim, were considered as substitute products. From the point of view of the problem being solved, in their advantages and disadvantages were determined.

1 Introduction

Consider the use of simulation systems for logistics problems. The complex of simulation models for the tasks of fleet and vehicle management is implemented in the AnyLogic simulation environment [1]. One of the main tasks of a corporate information system (CIS, this term means the totality of all information systems (IS) and their modules used in an enterprise) is the collection of information generated and used by various departments and employees formed by various modules and subsystems. Those. creation of a common information space of the company, ideally covering all corporate information. Over the past decades, the area of applicability of simulation systems (SIM) has significantly expanded:

First, simulation systems or software simulation models are embedded in the control circuit of the enterprise or organization, are integrated via data exchange interfaces with sensors, controllers, corporate information systems and thereby receive data on the current situation at the management site.

Secondly, the majority of SIM in the course of a simulation experiment allow you to change / update the original data and adapt the solution based on the situation.

Third, in most applied decision support systems that use a simulation subsystem or simulation model, formalization or decision improvement subsystems based on heuristics are used to formalize the knowledge of decision makers and control algorithms.

Such projects for the implementation of hybrid DSS (integrating a simulation model and a heuristic or optimization block) for logistics, production management and construction are described in [2–5]. Thus, it is possible to speak about open modules / systems of simulation modeling. It is also necessary to note the active use in the decision support systems of elements of expert systems (knowledge bases (KB) and logical inference machines (LIM) and ontologies.

As a means of simulation, the following systems can also be used: Simio simulation system; Business Studio business process modeling and ARIS; G2 Dynamic Expert System with ReThink simulation module; complex of the BPsim family, consisting of the BPsim.MAS dynamic situation simulation system and the BPsim.DSS decision support system [2-5].

Table 1 : Comparative analysis of simulation and multi-agent systems used in logistics

№	Parameter	G2	AnyLogic	Magenta	BPsim	ARIS	BS
1	Designing the structure of a conceptual model (ontology) / knowledge filling data (download geo-data, control rules)	NO /+	NO/+	+/+	+/+	+/NO	NO/NO
2	Process description						
2.1	Resources, facilities, converters	+/+/+	+/+/+	+/+/+	+/+/+	+/+/+	+/+/+
2.2	Hierarchical process model	+	+	NO	+	+	+
2.3	Agents	NO	+	+	+	NO	NO
3	Block heuristics	+	NO	+	+	NO	NO
4	Full cycle management					NO	NO
4.1	Reaction to an external event from the control object	+	NO	+	+	NO	NO
4.2	Dynamic planning	+	NO	+	+	NO	NO
4.3	Dispatching (rescheduling)	+	NO	+	+	NO	NO
4.4	Coordination and revision of plans on the fly	NO	NO	+	+	NO	NO
4.5	Monitoring and control of plan execution	+	NO	+	NO	NO	NO
4.6	Coordination of plans with the user	NO	NO	NO	+	NO	NO
4.7	Manual adjustment plan	NO	NO	NO	+	NO	NO
5	Subject specialist (dispatcher) interface	NO	NO	+	+	NO	NO

The program complexes listed in Table 1 have a number of shortcomings that limit or exclude the possibility of their use in solving the problem of designing a freight transportation planning and management system: the considered systems are not substantively focused on the problem being solved, there is no possibility of adjusting and coordinating the plan with the user (in the case of the Magenta system [6-7]) ; when planning a route, knowledge of subject specialists is not taken into account (in the case of ARIS, AnyLogic, Business Studio); the problem of partial adjustment of the re-planning of the vehicle route in the event of a new order is not solved (in the case of the Magenta system, the plan will be revised completely). The greatest opportunities for software implementation of the method of planning freight (fuel delivery) gives the family of DSS BPsim and Magenta.

2 Development Of a Hybrid Method Of Planning Fuel Delivery

The closest classical apparatus for planning fuel transportation is the transport problem [17-18]. In the course of the analysis of the applicability of the transport task, the following limitations of the subject area were revealed: 1) the multiplicity of the cargo transportation volume should be a multiple of the volume of the section; 2) the cargoes are not homogeneous and each cargo (depending on the type of fuel) can be transported in one section of the tank truck; 3) the sequence of fuel draining is not taken into account (depending on the design features of the drainage devices, the order of discharge of the sections may differ); 4) there is no time component in the form of start and end times of flights, loading / unloading times; 5) there is no division into types of goods or their marking (fuel types (for example, 92, 95, 98, Disel, 80), 6) the presence of several sections in the fuel tank truck is not taken into account; 7) do not take into account the physical limitations of gasoline tankers for filling stations; 8) there is no possibility to take into account the preferences of petrol tankers for filling stations; 9) does not take into account the possibility of servicing close gas stations by a gasoline tanker per flight. These restrictions are proposed to be taken into account using the multi-agent approach. The following approaches and models of multi-agent planning [2-5, 8-13] were investigated: 1) multi-agent model of the process of resource transformation (MAPP) [2-5]; 2) network of needs-opportunities (PV network) [6-7] V.A. Wittich, P.O. Skobelev, G.A. Rzhevsky; 3) model of active and passive transducers (AMS) Klebanov B.I. and I.M. Moskalev [14-15], as well as its change in the system of modeling of socio-economic development; 4) the approach Borshcheva AV, Karpova Yu.G., implemented in the AnyLogic [1] modeling system.

Table 2 : Analysis of approaches to solving problems of supply

Criteria / methods	Transport problems	Simulation	Expert systems
Model adequacy issues			
Use of funds (vehicles)	+	+	NO
Resource flows (traffic volumes): NB-AGS, NB-Fuel truck-AGS	+/NO	+/+	+/+
Time of transportation, loading, delivery plan	NO	+	NO
Heuristics of the decision maker model, planning agents	NO	NO	+
Problem solving support			
Restricted planning - time / resources / funds.	NO / + / +	+ / + / +	NO / + / +
Analysis of process bottlenecks	NO	+	NO
Dispatching	NO	+	NO

To solve the problem of planning the delivery, a hybrid method was developed based on the integration of the transport problem, the theory of scheduling, the apparatus of simulation, and expert modeling, multi-agent systems (MAPP). The method consists of the following steps:

1. Calculation (determination) of the fuel needs at the filling stations of the multiple capacity of the minimum gasoline tank truck. The forecast of requirements for the remaining capacities of the filling stations, in which for the second half of the shift the demand, which is a multiple of the capacity of the minimum gasoline tank truck, can enter into%. The solution of the transport task with regard to the planning of deliveries from oil depots to gas stations (without linkage of gasoline tankers).
2. Processing of the supporting solution from the transport task 1: All the needs are ranked (the most urgent needs are identified - what we carry earlier, and what is later) - according to the priority. The definition for each order (supply requirements) of the supplier (warehouse / logistics center - tank depot) and the route of delivery.
3. Processing of the supporting solution from the transport task 2: Creation of flights (transportation plan). Assigning for each order a vehicle and determining the time of execution (the times of the beginning and end of the voyage). At this stage, an intelligent scheduling agent is used with a frame knowledge base that takes into account the statistics of fuel sales from the gas station, the physical limitations of gas stations and gasoline tankers (by their compatibility and service capabilities), and also the preferences for use.
4. Verification of the logistics plan by the logistics specialist / dispatcher.
5. Verification and adjustment of the export plan on the multi-agent simulation model of the resource conversion process.

6. Implementation of the plan.
7. In the conditions of external influences leading to dispatching situations, the expert's plan for the dispatch is being adjusted by the expert (dispatcher). The main criterion for the success of this task is to ensure the uninterrupted operation of the network of filling stations.

3 Program Realization Of a Hybrid Method Of Fuel Delivery Planning

Based on the hybrid decision-making method for fuel distribution planning through the filling station network, decision support system (DSS) was developed as a result of the integration of the "Planner", BPsim.MAS (multi-agent modeling system) and BPsim.DSS (frame intelligent system) systems. This DSS is problem-oriented and supports manual, automated and automatic updating of the plan for export by the expert (dispatcher). The architecture of the MAPP agent is based on the hybrid architecture of InteRRaP [5, 16] and is shown in Figure 1.

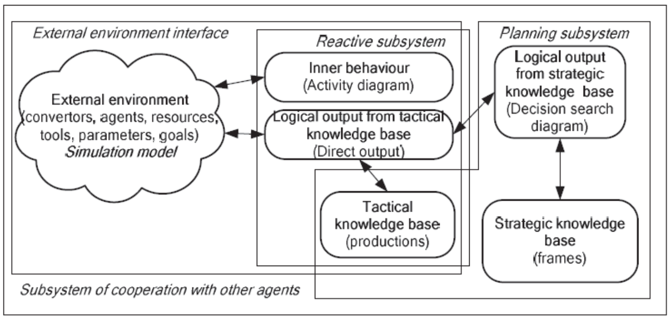

Figure 1: Architecture of the agent of MAPP

The model of the MAPP / DSS according to the model of the MAPP and the hybrid architecture of InteRRaP allows to develop solutions both with their verification on a multi-agent simulation model and without it (in this case, real data from the corporate information system is received by the "Scheduler" agent's sensors, and the result of its operation formed plan) is issued through effectors. According to the InteRRaP-architecture, the model of the MAPP agent consists of 4 levels [5]:

1. The model of the external environment corresponds to the following elements of the MAPP: converters, resources, reactive-intelligent agents, facilities, parameters, targets. The external environment performs the following functions: generates tasks, transmits messages between agents, processes agent commands (performs resource conversion), changes the current state of the external environment (transfers Sn to Sn + 1). The external environment is a model of the control object, built from the elements of the MAPP. The control object model describes the processes of fuel consumption at filling stations, the work processes of filling stations, oil depots, and fuel supply processes.
2. Components of the interface with the outside world and reactive behavior are implemented in the form of the agent's production rules (tactical KB) base and the inference engine (the simulator algorithm).
3. The level of local planning is designed to find effective solutions. The component of local planning is implemented on the basis of the frame KB (it is a frame-based - in the figure the strategic KB).
4. The subsystem of cooperation with other agents allows integration with hybrid agents of the MAPP, as well as with external information systems.

The design of the conceptual domain model [2-5] and the knowledge base (KB or DB) of the agent's local planning is implemented on the basis of the extension of the UML class diagram. The mechanism of logical inference for this KB is realized through the diagram of solution search, constructed on the basis of the sequence diagram [6]. Each decision in the KB is an agent's action plan. Each plan consists of a set of rules from the base of the reactive component. Based on the solution found, the agent's current plan is updated. The search of all variants contained in the KB forms the library of agent plans.

4 Application Of Frame Approach In The Program Agent "Scheduler"

An example of a solution search chart for the sub task manager for distribution of requests-needs from gas stations in gasoline tank trucks in the visual designer of the logical output engine BPsim.DSS for the "Scheduler" agent (figure 2).

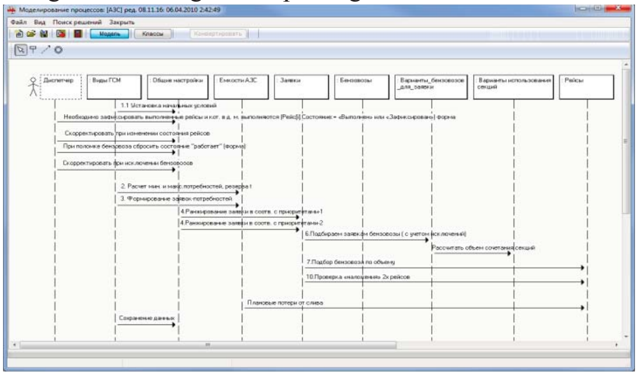

Figure 2: Chart of the search tree of decisions "Planning of a delivery of fuel. Distribution of requests on fuel trucks"

The visual interface of the manager of the agent "Scheduler" is shown in fig. 3.

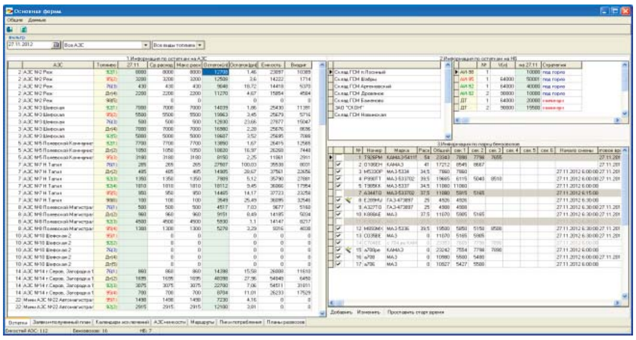

Figure 3: Visual interface of the manager

The use of the frame output engine and the visual interface of the dispatcher allows you to flexibly resolve the situations associated with dispatching. Dispatching situations that require minimal plan adjustments are handled by the decision maker using a visual interface. In cases of significant adjustment of the plan or complete rebuilding - the script of the inference engine is used. The results of computational experiments of the simulation model are compared with the actual data of the transfer and showed the convergence of the results in part of the flights and the volume of fuel transportation. The results of the analysis prove that the method implemented in the DSS shows a greedy strategy for the number of flights and the volume of traffic (on average 13% higher). However, the method is inferior to the actions of the dispatcher in terms of the volume of fuel given by the export strategy by 1.4%. As a result of the implementation, multi-agent models of the supply chain network processes in the BPsim.MAS dynamic situation modeling system and the BPsim.DSS decision-making system, as well as the "Scheduler", which implement scheduling and scheduling algorithms, were developed. The results of the experiments on the data showed the following results:

1. the pilot plan provides consistency with the results of the actual plan compiled by the dispatch specialist;
2. the use of automatic scheduling algorithm allows to take into account the preferences of the person making the decision, in terms of delivery strategies, the priority of servicing of the filling station capacities, restrictions on vehicles (petrol tankers) and gas stations (in the part of servicing with gasoline tank trucks).

The main criterion for the success of the task is to ensure the smooth operation of the network of gas stations. Even if the profit will be maximal in a risky variant, it will be eliminated, since the interruption or malfunction of the gas station may cause an outflow (loss) of customers both of the gas station and the entire network in the future.

The work of Janychivin Oyuungarel [19] describes the development of an optimal plan for the delivery of petroleum products. The optimization of the plan was carried out with restrictions on the carrying capacity of vehicles and the length of the route based on the traveling salesman problem and the work. The results of the comparison of this approach and the new method are presented in Table 3.

The approach [19] has the following limitations:

1. each client is served by only one route;
2. considered 1 type of cargo;
3. the task of selecting the carrying capacity of vehicles and their optimal number is solved, however, the carrying capacity of all vehicles is the same in one experiment;
4. one warehouse (tank farm);
5. the duration of the shift is not limited in time;
6. partial filling of a gasoline tank truck with oil products (sections) is admissible, which contradicts safety regulations, although sectional nature of gas tank trucks is not mentioned;
7. route planning is carried out without taking into account the urgency of supply, restrictions on filling the sections of fuel trucks.

Table 3 : Comparison of methods for planning petroleum products supply network of gas stations

Parametr for compare	Method Janychivin Oyuungarel [21]	New method
1. Restrictions on the carrying capacity of vehicles	+	+
1.1. Vehicle carrying capacity is the same.	+	+
1.2. Load capacity of vehicles is different	NO	+
1.3. There are sections in vehicles	NO	+
1.4. Partial filling of the section is not allowed.	NO	+
2. The ability to service multiple gas stations in one route (flight)	+	+
2.1. Each client is served by only one route.	+	NO
3. The number of types of petroleum products	1	N
4. Customer demand (gas station needs)	constant	variable
5. Time limit for the shift (plan)	NO	+
6. Accounting for hourly sales statistics	NO	+
7. The solution to the problem of route planning	+	+
8. Support dispatch task	NO	+
9. Number of warehouses (tank farms)	1	M

Currently, the network of gas stations can be implemented with a dozen different types of fuels; needs of one gas station can be provided from several warehouses (NB), which violates the restriction on one route for 1 client; at individual gas stations there are up to 7-8 tanks, and the number of sections on average in modern fuel trucks is 2-4, which also violates the restriction on 1 route. The use of AARS also often does not allow for the introduction of this restriction, due to the fact that the capacity of AARS is less than that of stationary ones and their oil product supply often requires two deliveries per shift (at the beginning and end of the shift). Thus, the new hybrid method of planning for petroleum products supply network of gas stations is more flexible and meets the requirements of the subject area.

5 Conclusion

In this paper, we propose a hybrid method for deciding the problem of planning the transportation of fuel through a network of gasoline stations. The method was developed as a result of the integration of the transport task, the multi-agent simulation model of the process of resource conversion, the apparatus of frame expert systems. The method is implemented in software as a decision support system as a result of the integration of the "Scheduler" and BPsim systems. Approbation of the method and DSS took place in the current network of gas stations in the Sverdlovsk region. When solving the task of planning the delivery, the task of integrating the DSS with the corporate system of the enterprise was solved, which now makes it possible to classify BPsim as an open modeling system and makes it possible to apply it to real-time control tasks.

Acknowledgment

The work was supported by Act 211 Government of the Russian Federation, contract № 02.A03.21.0006.

References

1. AnyLogic simulation software. https://www.anylogic.com/
2. Aksyonov K., Bykov E., Aksyonova O., Goncharova N., Nevolina A. Decision Support for Gasoline Tanker Logistics with BPsim.DSS. International Conference on Computer Information Systems and Industrial Applications (CISIA 2015). June 28-29, Bangkok, Thailand. P.604-606. WOS:000359866200164.
3. K. Aksyonov, E. Bykov, O. Aksyonova, N. Goncharova and A. Nevolina, Extension of the multi-agent resource conversion processes model: Implementation of agent coalitions. 5th International Conference on Advances in Computing, Communications and Informatics, ICACCI 2016; LNM Institute of Information Technology (LNMIIT)Jaipur; India; 21 September 2016 through 24 September 2016. Pages 593-597. DOI: 10.1109/ICACCI.2016.7732110 URL: http://www.scopus.com WOS:000392503100094.
4. Aksyonov K., Bykov E., Aksyonova O. Petrol delivery management with BPsim.DSS. 33rd Chinese Control Conference, CCC 2014; Nanjing; China; 28 July 2014 through 30 July 2014, Pages 7628-7632.
5. K. Aksyonov, E. Bykov, E. Smoliy, E. Sufrygina, O. Aksyonova and Wang Kai Development and Application of Decision Support System BPsim.DSS // Proceedings of the IEEE 2010 Chinese Control and Decision Conference (CCDC 2010), 26-28 May 2010, Xuzhou, China, Pages 1207-1212.
6. V. A. Wittich, P. O. Skobelev, ―Multi-agent interaction models for the design of the nets of requirements and capabilities in open systems‖, Automatics and telemechanics, vol. 1, 2003. pp. 177-185.
7. Skobelev P. O. Multi-agent technologies for the control of resources in real-time. Proceedings of the seminar―Mechanics, control and informatics‖, track ―Perspective computer systems: devices, methods and concepts, Tarusa, 2-4 March 2011. http://www.iki.rssi.ru/seminar/2011030204/presentation/201 10303_03.pdf (accessed: 13.04.2016).
8. Wooldridge M. Agent-based software engineering. IEEE Proc. Software Engineering. — 1997, № 144 (1). — P. 26–37.
9. Kowalski M., Zelewski S., Bergenrodt D., Klupfel H. Application of new techniques of artificial intelligence in logistics: an ontology-driven case-based reasoning approach. Proceedings of ESM'2012 (ESM - European Simulation and Modelling Conference) October 22-24, 2012, FOM University of Applied Sciences. — Essen, Germany. — P. 323-328.
10. N. R. Jennings, On agent-based software engineering // Artificial Intelligence. — 2000, vol. 117, — P. 277-296. - URL:http://www.agentfactory.com/~rem/day4/Papers/AOSEJenni ngs.pdf [retrieved: 05, 2014].
11. Sokolov B.V., Pavlov A.N., Yusupov R.M., Ohtilev M.U., Potryasaev S.A. Theoretical and technological foundations of complex objects proactive monitoring management and control // Proceedings of the Symposium Automated

Systems and Technologies Peter the Great St. Petersburg Polytechnic University, Leibniz Universität Hannover. 2015. P. 103-110.
12. Solovyeva I., Sokolov B., Ivanov D. Analysis of position optimization method applicability in supply chain management problem // 2015 International Conference "Stability and Control Processes" in Memory of V.I. Zubov (SCP) 2015. P. 498-500.
13. Devyatkov, V.V., Vlasov S.A., Devyatkov T.V. Cloud Technology in Simulation Studies: GPSS Cloud Project // Proceedings of the 7th IFAC Conference on Manufacturing Modeling, Management, and Control. – Saint Petersburg (Russia): IFAC, June 19-21, 2013. – Volume 7. – Part 1. – P. 637-641.
14. Klebanov B., Antropov, T., Riabkina, E. Bases of imitation model of artificial society construction accounting of the agents' needs recursion. 16th International Multidisciplinary Scientific GeoConference SGEM 2016. Book2 Vol. 1, 101-108 pp. URL:https://sgemworld.at/sgemlib/spip.php?article8493 DOI: 10.5593/SGEM2016/B21/S07.014, WOS:000395499400014.
15. Klebanov B., Antropov, T., Riabkina, E. The principles of multi-agent models of development based on the needs of the agents 35th Chinese Control Conference, CCC 2016 C. 7551-7555 DOI: 10.1109/ChiCC.2016.7554553 URL : http://ieeexplore.ieee.org/document/7554553/ , WOS:000400282203147
16. Muller J.P. & M.Pischel. 1993. The Agent Architecture InteRRaP: Concept and Application, German Research Center for Artificial Intelligence (DFKI).
17. Galyutdinov R.R. Transportation problem-decision of potential method http://galyautdinov.ru/post/transportnaya-zadacha ;
18. Prosvetov G.I. Mathematical method in logistic: problem and decision: Alfa Press, 2014. 304 p.;
19. Janychivin Oyuungarel. Control methods improving petrol supply: for example of Mongolia. Moscow 2006.