Adaptive routing in the mechanical transport systems on the basis of knowledge

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Abstract. This paper investigates the adaptation of flows in mechanical transport system, based on the use of expert knowledge about its behavior. It is assumed that the examiner observing the behavior of traffic on a running system, generalizes and displays its experience by allocating subsystems with a small change in bandwidth. Thus, the overall system is represented by the collection of subnets of different capacity at different time intervals. The routing problem is to find the ways of transporting of cargo in the specified time with minimal effort. A comparative analysis of algorithms of dynamic and fixed routing is performed. A model of fuzzy temporal hypergraph is used to create routing tables. Subnet with fuzzy stable bandwidth correspond vertices of the hypergraph. Modification of the Dijkstra's algorithm is given for the case of using fuzzy temporal hypergraph. The quality of adaptation parameters of time and resource costs is evaluated.

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Introduction

Mechanical transport system (MTS) includes a network of conveyors and switches. Conveyors form a network in which key parts direction switchers are situated. The switcher is a mechanical device which directs the cargo unit from one output conveyor to one of the inputs of the adjacent conveyors. Modern airports are used MTS luggage delivery. The problem of delivery of the goods to the right point in a given time with minimal costs is relevant to the MTS. There are objective difficulties in the construction of an analytical model of flow in the MTS. A promising way to solve it is to use intellectual methods for solving complex problems. As noted in [1], "strong" method of solution is the use of experience. The experience of experts serving the MTS could be the basis of adaptive routing methods that take into account the specific features of the operating conditions. In the presence of powerful sources of programming and configuration of embedded control systems MTS [2] there is a possibility of evolutionary development of the MTS as a system to accumulate and use knowledge.

Fixed and dynamic routing MTS

Routing methods used in the transport networks can be divided into fixed and dynamic routing methods. Fixed routing uses unvaried routing tables. The tables loaded into the memory of controllers from a control center of MTS. Dynamic routing changes the routing table if the state of the environment of transportation changes. Each controller updates the table independently in accordance with the information received from the neighboring network controllers.

The main advantage of a fixed routing is its easy implementation. If the traffic flow and the capacity of the network are stable, the routing can be based on well-known algorithms for finding the shortest path or the shortest path tree [3]. Significant changes in the network settings require a reboot of tables.

Let us indicate flaws of the fixed routing:

• Incomplete and inaccurate data about the characteristics of the transport network forces to simplify and generalize during the construction of routing tables;

• Hypotheses about the stability of the traffic flow and the parameters of the network are not always true.

Application area of the fixed routing is relatively simple MTS, operating in a stable environment.

Implementation of the dynamic routing uses the procedures of updating tables during the process of functioning. Choosing the best route in the MTS can be based on well-known Bellman-Ford algorithm [3]. The use of this method of routing encounters the following problems:

• The metric of the distance between key parts is determined subjectively. The distance in a generalized sense refers to the time, cost, and reliability of transportation. Therefore, the concept of distance is different, even within the network for its various edges. As a result, the operations of simple arithmetic summation and comparing the distances are not applicable;

- The time, cost, and reliability of transportation vary unpredictably over time. To obtain accurate analytical expressions for their determination is not possible.

Uncertainty and volatility of transportation terms makes us to use routing models, focused on knowledge. Different approaches, determined by the source and form of knowledge representation were investigated there [4]. Little-investigated is the case when there are expert knowledge relating to the behavior of input flows of cargo and the behavior of traffic flow within the MTS. Such knowledge is integrally reflect the relationship of many factors such as the condition and reliability of mechanical means of transportation and cargo management, the impact of the flow of cargo on MTS, changing the qualities of the cargo during transportation. The capacity of the experts is not limitless. For example, experts are able to specify how accurate the schedule of the emergence of luggage parties at the airport is hold, what is the approximate size of the parties, the properties of cargo units (size, type of packaging, shape, weight), the possible points of congestion of the flow, the areas of overload. But they are not able to formulate the rules of behavior of a single routing key part in conditions of low or high network load. Models, based on which the knowledge of experts, computing and communication capabilities of MTS controllers would be effectively applied, are required.

The general formulation

The general problem has the following form. There is a transportation network that moves lots of cargo between its key parts. In the lot of cargo there are N units and each unit is moved from a sender key part to the receiving one for the time $t_i (i = \overline{1, N})$ while passing the route length $l_i (i = \overline{1, N})$. In the process of passing the route failures and breakdowns f_i from the variety of allowable defects F can occur. The occurrence of congestions in the flow, sending errors, damaging cargo unit, etc is meant by defects. Routing is to solve the problem [5]:

$$\begin{cases} \sum_i l_i \to \min, \\ \max(t_i) < t^*, \\ f_i \subseteq F, \end{cases} \qquad (1)$$

where t^* is the time limit of transportation of a unit of cargo. Taking into account these difficulties, we will assume that the problem is solved on the basis of expert knowledge about the behavior of traffic flows. This knowledge is expressed in the form of guidance on the scheme of MTS subnets and their properties – transport time (T_k), the length of the route (L_k) and possible defects (F_k). Also the interval of time$[t_a, t_b]$ is indicated, during which the properties retain their value constant. All property values and values of the time interval are fuzzy. Thus, the stability and uniformity of transport processes in the subnet are supposed.

Fig. 1 shows an example of description of knowledge. The MTS scheme displays overlapping areas which restrict subnets. Let us represent the structure of the MTS as a temporal hypergraph [6, 7] $G = (V, E_t)$ with a set of vertices V and the set of edges E_t whose weights change over time:

$$E_t = (w_i, \widetilde{t}_i).$$

Here, w_i is the weight of the edge, $\widetilde{t}_i$ is a time interval during which the edge keeps the weight constant.

In this paper we investigate the implementation of the fixed and dynamic routing if you have experience, displayed by hypergraph of the kind described. The aim of the investigation is to identify factors that affect the quality of the solution of the problem (1).

Creating of fixed routing tables

The organization of fixed routing is based on the assumption that the behavior of traffic flows is stable. This means:

- Stability of schedule of the appearance of cargo parts on the key parts-sources;
- Fixity of the stream of defects in subnets.

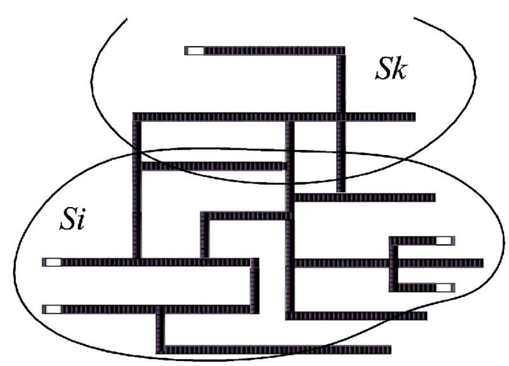

Fig. 1. The example of description of knowledge

The properties of each edge of the hypergraph are:

1) The fuzzy value of time to transport a unit of cargo. Fig. 2 shows an example of graphic description. Every region in the coordinate system wt represents the most significant, from the standpoint of the expert, value of transportation time. The possibility of graphic description is extremely important for authors because it increases the quality of the acquired knowledge. Formally with the help of zones in Fig. 2 linguistic variables with terms of the "less than w_i ", "equal w_i " and "greater than w_i " can be described;

2) The fuzzy value of path length. Its description is similar to the above;

3) A subset of the set of defects.

The routing tables for each key part of MTS are formed as a result of finding the shortest path between a given pair of vertices of temporal hypergraph. The problem of finding the shortest route in the case of the temporal dependence of the weights of the hypergraph is formulated as follows: a hypergraph $G = (V, E_t)$, dependence $E_t = (w_i, \tilde{t}_i)$, the time of moving off the route t_0, and a pair of vertices (v_b, v_e) that do not lie on the one edge of a hypergraph are given. It is necessary to find a route from v_b to v_e of minimum weight.

To solve the problem, ideas of famous search algorithms for the shortest paths in graphs can be used [8]. The implementation of an idea would be different in that way that it should include an analysis of the reachable vertices in a given time interval. It is believed that the vertex v_i is reachable from the vertex v_j on the time interval $[t_a, t_b]$, if there is a path from v_j to v_i containing only edges with nonzero weight ($w_i > 0$).

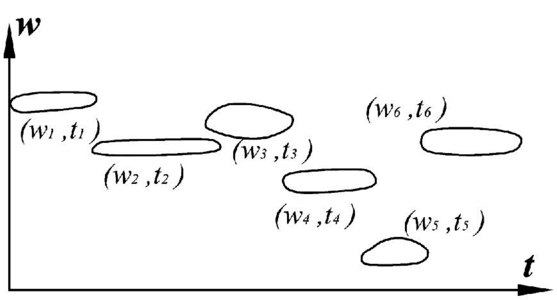

Fig. 2. The example of graphic time value description

As an example, let us consider a modification of Dijkstra's algorithm. The algorithm consists of the following steps:

1) to set the number of iteration $k = 1$, as subsidiary hypergraph to use $g^{(0)} = \{v_b\}$, to set the current point of the analysis on the time axis $t^{(0)} = t_0$;

2) to find all the vertices in the hypergraph G that can be achieved from vertices $g^{(k-1)}$ at a point of time $t^{(k)} = \min\limits_{v_i \notin g^{(k-1)}} (t^{(k-1)} + \tilde{t}_i)$. Let us set the subgraph g' that includes all selected vertices and directed lines of the hypergraph G, connecting it with the hypergraph $g^{(k-1)}$;

3) to construct a subsidiary hypergraph $g^{(k)} = g^{(k-1)} \cup g'$;

4) to mark the vertices $g^{(k)}$ according to the Dijkstra's algorithm. If among definitively marked vertices v_b appears, go to step 6, otherwise to go to step 5;

5) set $k = k + 1$ and go to step 2;

6) the end.

The resulting solution is converted to the schedule of switching cargo flows at all key parts of the MTS, which are on the fast track.

For the case of a fuzzy set of the parameters of the temporal hypergraph algorithm uses summation and comparison operations of fuzzy intervals of time and weights of edges defined by fuzzy numbers [9-12].

Analyzing the algorithm, we should make a number of conclusions.

Malfunctions and failures in the MTS do not appear explicitly in the process of building the routing tables. These factors experts consider indirectly through time delays and additional resource costs for transportation. It is useful that the MTS becomes insensitive to malfunctions and failures, but subjectivity can lead to significant redundancy of the system.

The subsequent summation of fuzzy values of the weights of the edges of the hypergraph leads to growing uncertainty of the outcome. The more vertices of the hypergraph are in the fast track, the higher the uncertainty is. Therefore, the effect of fixed routing is to be expected in MTS with a few subnets.

Getting a higher degree of certainty is only possible due to the decomposition of the existing subnets to the networks with a smaller number of key parts. Expert observers of MTS should allocate subnets with sustainable behavior. Formally, this will lead to a decrease in the degree of fuzziness of weights of edges of the hypergraph $E_t = (w_i, \widetilde{t}_i)$. We can assume that the deepening of such knowledge is limited and that will determine the final result of the decomposition of MTS.

Dynamic routing between subnets MTS

The essence of dynamic routing is an existence of adaptation mechanism to the current situation in the MTS. The situation changes due to failures and breakdowns of technical equipment, failures in the chart of the arrivals of cargo flows, damage of cargo. Choosing the transportation route is more complicated because it uses logic of estimation of the situation.

Expert observing network is unlikely to formulate rules of routing in network's key parts. For him it is more natural to state that certain areas of the MTS are either work normally or over-loaded or under-loaded, etc. Therefore, let us consider routing model based on expert knowledge on the state of subnets.

Let us assume that each subnet of MTS can be in one of the many possible states. Minimum two states are possible. They are associated with the operability and no operability of the subnet. It is appropriate to introduce larger number of states for more accurate cargo management.

Let us introduce a linguistic variable *S* which values correspond to states of the subnet, and the domain is the number axis of the path length on the conveyer. Then fuzzy value of path length can be matched to each linguistic value. Fig. 3 shows an example of the membership function for a term-set S consisting of the values {"weakly loaded subnet", "subnet in the normal mode", "subnet in overload"}. Similarly, we can define the variable of transport time through the subnet.

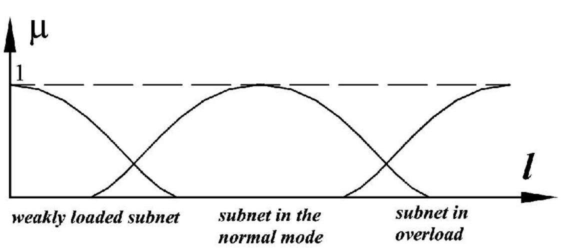

Fig. 3. The example of the membership function for a term-set linguistic variable

It should be noted that the values of the linguistic variable is natural to associate with the names of the defects. For example, the values of "subnet with small jams", "subnet stuck with oversized cargo", "subnet with misdirected cargo units" and similar ones simplify the task of the expert and allow you to gain valuable knowledge, explicitly linking defects to the cost and time of transportation.

Let us imagine MTS as fuzzy hypergraph $G = (V, E_t^{'})$, where $E_t^{'} = (w_i(s_j)), s_j \in S$. Weight of the edge $w_i(s_j)$ is a function of the state of the subnet, which is a fuzzy linguistic variable. Routing problem is to find the shortest path between a given pair of vertices (v_b, v_e) that do not lie on the same edge of the hypergraph.

The solution of the problem can be obtained by Dijkstra's algorithm, modified in case of fuzzy weights of the edges of the hypergraph. The modification does not affect the logic of tagging and bypass of vertices, but refers to the implementation of two major operations: summation of the weights of edges and their comparison.

Any given linguistic value S is matched with a fuzzy set $\{\mu_1 / x_1, \mu_2 / x_2, ..., \mu_Q / x_Q\}$, where Q is the number of terms S, X is the base set. The addition of sets is proposed to carry out on a well-known principle: the sum of fuzzy sets A and B is the set of elements

$$\min(\mu_a, \mu_b) / a + b,$$

where $\mu_a / a \in A$ and $\mu_b / b \in B$ are any pair of elements of two initial fuzzy sets. Thus, by increasing the number of edges in the path the cardinal of set increases.

Comparison of the paths length is proposed to be made through a comparison of the "centers of gravity" of fuzzy sets [11]. If A and B are not clear paths,

$$A < B \Rightarrow \Big(\sum_{\mu_i / a_i \in A} a_i \mu_i / \sum \mu_i \Big) < \Big(\sum_{\mu_i / b_i \in B} b_i \mu_i / \sum \mu_i \Big)$$

Let us note the implementation feature of the routing tables, which are constructed from the resulting solution on hypergraph. The problem of dynamic routing allows many decisions: if the MTS has M sub-systems with Q states, the total number of states of the MTS will be Q^M. Each state corresponds to a hypergraph G with M edges, in which the route of minimum weight from a given vertex v_b to the vertex v_e is determined.

Accordingly, the number of routes with the minimum weight will also be Q^M . Keeping all the decisions in the memory of controllers is problematic because of the large size of tables. However, the routing table is redundant as only a small fraction of the states of MTS is realized in practice. This part can be specified only by the expert observing the system. Consequently, expert knowledge will allow realizing solutions to the optimization problem (1).

Analyzing the dynamic routing in the MTS, we should make the following conclusions.

Dynamic routing explicitly takes into account the defects in the work of the MTS. Focusing on the knowledge of experts in this case helps to reduce the uncertainty of behavior MTS when defects occur. To gain knowledge of a higher quality, it is necessary to use fuzzy linguistic variables to describe the states of MTS.

A major problem of the implementation is a significant amount of controllers' memory for storing routing tables. The solution to this problem can also be found from experiences of overseeing the MTS by experts.

Conclusion

In this paper we analyzed the approach to the intellectualization of MTS, based on the use of expert knowledge, overseeing the operation of the system. Knowledge control the construction of tables of fixed and dynamic routing.

In constructing the routing tables it is advisable to use a model of fuzzy temporal hypergraph. Due to the modification of known methods of finding the shortest routes in graph the problem of minimizing the resources of transportation with the restriction on a delivery time and the set of admissible defects can be effectively solved.

The procedure of the intellectualization of MTS included in the design process gives it an evolutionary character. Every working MTS can improve routing through the accumulation of experience in their own exploitation.

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References

1. Luger, G.F., 2004. Artificial Intelligence: Structures and Strategies for Complex Problem Solving. Addison Wesley, pp. 912.
2. Black, G., V. Vyatkin, 2011. Intelligent Distributed execution and cyber-physical design of Baggage Handling automation with IEC 61499. In the Proceedings of the IEEE Int. Conf. on Industrial Informatics, pp. 573-578.
3. Cormen, T. H., C. E. Leiserson, R.L. Rivest and C.Stein, 2009. Introduction to Algorithms, 3rd ed. MIT Press, pp. 1312.
4. Zhao, K., B. Liu, T.M. Tirpark, and X. Weimin, 2005. A Visual Data Mining Framework for Convenient Identification of Useful Knowledge. In the Proceedings of the IEEE International Conference on Data Mining Pages, pp. 530-537.
5. Bozhenyuk, A. and E. Gerasimenko, 2013. Methods for Maximum and Minimum Cost Flow Determining in Fuzzy Conditions. World Applied Sciences Journal, 22 (SPL.Issue2): 76–81.
6. Bershtein, L.S. and A.V. Bozhenyuk, 2008. Fuzzy Graphs and Fuzzy Hypergraphs. In: Dopico, J., de la Calle, J., Sierra, A. (eds.) Encyclopedia of Artificial Intelligence, Information SCI, Hershey, New York, pp: 704-709.
7. Bershtein, L., A. Bozhenyuk, 2005. Fuzzy graphs and fuzzy hypergraphs. Moscow Scientific world Press. pp.256.
8. Berge, C., 1989. Hypergraphs: Combinatorics of Finite Sets. North Holland, pp. 267.
9. Zimmerman, H.-J. 1991. Fuzzy Set Theory and Its Applications, 2nd ed. Boston/Dordrecht/London: Kluwer Academic Publishers, pp. 399.
10. Dubois, D., H. Prade, 1978. Operations on fuzzy numbers. International Journal of System Science, 6: 613-626.
11. Bozhenyuk, A., I. Rozenberg, 2012. Allocation of Service Centers in the GIS with the Largest Vitality Degree. Communications in Computer and Information Science. Advances in Computational Intelligence, 298(2): 98–106,
12. Belyakov, S., M. Savelyeva and I. Rozenberg, 2013. The construction of fuzzy based on case-based reasoning. In the Proceedings of the 19th International Conference on Soft Computing MENDEL, pp. 273-276.