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Procedia Engineering 69 (2014) 622 – 629

Procedia Engineering

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24th DAAAM International Symposium on Intelligent Manufacturing and Automation, 2013

Selected Heuristic Methods used in Industrial Engineering

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Abstract

This paper deals with a heuristic approach to material supplies of assembly lines (e.g. automotive industry) and to optimization of a stacker which is used in production lines or stores. A modern method for supplying assembly lines with material is using the so called 'milk run' – trains supplying not only one point in assembly production lines but several points. A graph model is used. An analytical solution for creation of trains is not known; most probably it does not exist. Solutions using "brute force" may be very slow. They cannot be used for more than a dozen demands.
A repeated random selection of n-tuples of transport demands and building of trains from this selection could be a good way to solve this task.
A model of assembly production lines has been developed and the speed of convergence of random selections to a suboptimal solution has been calculated and measured. A thousand selections give good results. These heuristic results have been compared with some deterministic strategies (nearest demand, building of n-tuples).
A similar approach has been used for optimization of a stacker in a workshop and in a store.

Keywords: using graphs in logistics; material supplies; heuristic optimization -assembly lines - milk run; FMS; stacker

1. Introduction

Any production enterprise is nowadays focused more than ever before to optimize production costs. This means not only cost savings but also lowering risks of order delay and due dates. Computers are increasingly used and therefore there is a shift from decisions made by production management based on long-term experience and intuition to a growing support from computers. It is accordingly necessary to study and develop algorithms leading

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doi:10.1016/j.proeng.2014.03.035

to optimization of costs and lowering of potential risks.

Optimization methods and algorithms have been studied and developed at the Department of Industrial Engineering and Management for a long time [1].

Optimization methods have been explored and researched in the following fields:

- Moves of a stacker and two stackers on one rail
- Operative plans of production
- Daily plans of production [2]
- Selecting appropriate picking method [3]

While researching these tasks we came to the conclusion that too sophisticated methods mostly fail due to the inaccuracy of the input data. This inaccuracy is more caused by dynamic changes in this process and its development in time than by insufficient quality of work in technical preparation of the production, inaccurate observations and measuring in the production process. Because of this, research and development activities have been focused more on simple and robust methods of optimization which could be both easier in implementation and resistant to changes of parameters of optimized systems.

Other authors ([4], [5], [6] [7], [8],[9],[10],[11]) solve the optimization in industrial engineering using mathematic models and elaborated heuristic optimization techniques.

2. Assembly line supply system

Experiments with simulation and optimization of supply routes in the automotive industry have been carried out by cooperation between the university and industry. There is a growing trend of changing from fork lift trucks to manual or automatic trains. These trains consist of a tractor and some carriages. Two strategies exist:

- Detaching a carriage on the supply point at the assembly line: the last carriage is detached at the supply point, it depends on the sequence of carriages. This sequence is created in the central store. Empty carriages are collected after separation of the last carriage with material.
- Taking off material from the carriage directly at the workplace: in this case, the length of a train stays constant and there is no need to collect the empty carriage. Manipulating material at workplaces takes longer than detaching a carriage.

If carriages are not detached it is also possible to distinguish:

- One carriage transports material only to one supply point
- One carriage transports material to many supply points: in this case the new task is for optimal filling of a carriage both from the point of view of carriage capacity and manipulation at the workplace

3. Test model of a production line supply system

A test model of assembly lines supplied by logistic trains based on experience acquired by the analysis of production lines in an automotive enterprise has been developed (Fig. 1).

Fixed supply routes have not been considered because there is no possible optimization. Dynamically created routes have been found according to the momentary state of transport demand. The length of trains varies from 1 to 4 carriages which means delivery for a maximum of 4 points in the assembly line. Carriages are detached at supply points. Collations of empty carriages are not solved because they are in principle simpler than transportation of carriages with material.

This model has been transformed into an orientated mathematic graph with 21 vertices in which 0 is the central store (U00) and start of every transport of a maximum of 4 carriages (Fig. 2).

Groups of n demands $(1 < n < 20]$ are randomly generated from vertices needing service by trains. Every group can be considered as a subgraph. The task is to cover the subgraph with circles of a maximum of 5 vertices (start in the central store and 4 supply points in assembly lines) so that the total length of these circles representing the routes of individual trains will be the shortest of them.

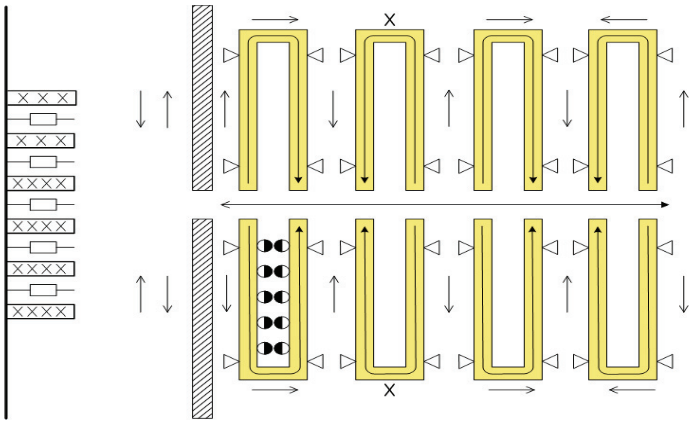

Fig. 1.Scheme of assembly lines and supply routes.

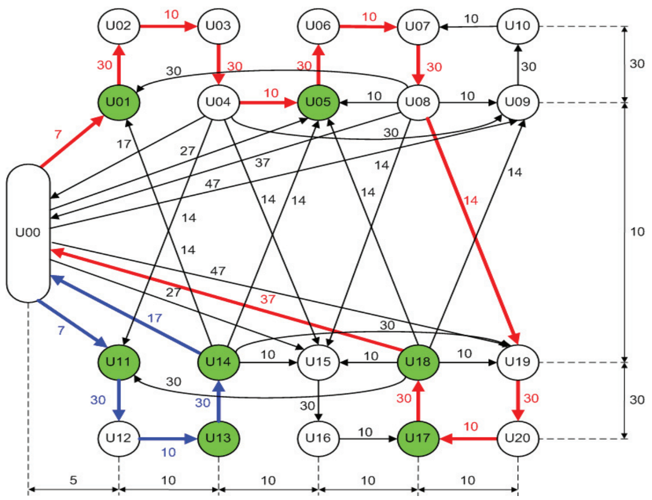

Fig. 2.Graph representation of assembly lines and supply routes.

4. Deterministic solutions

On the basis of an analogy with production scheduling, it is possible to consider some deterministic algorithms:

- Selection of the nearest demand, then of the demand nearest to the goal of the last selected demand up to the maximum length of the train. The next trains are selected in the same way.
- Selection of the farthest demand, then of the demand nearest to the goal of the last selected demand up to the maximum length of the train. The next trains are selected in the same way.

5. Heuristic solutions

5.1. Solution by brute force

The solution by brute force means searching all possible permutations, which are n!. There is a common assertion that this solution is possible only for very small n. Therefore a test program has been developed which measures the time needed for evaluation of all permutations of n demands. The results were surprising.

Table 1.Times for solutions with brute force.

n	factorial	Sec	min
2	2	0.000	0.000
3	6	0.000	0.000
4	24	0.000	0.000
5	120	0.000	0.000
6	720	0.000	0.000
7	5 040	0.000	0.000
8	40 320	0.003	0.000
9	362 880	0.029	0.000
10	3 628 800	0.277	0.005
11	39 916 800	3.020	0.050
12	479 001 600	36.082	0.601
13	6 227 020 800	489.931	8.166
14	87 178 291 200	7 000.000	116.667

It ensues from the table that optimization by brute force is possible on a common PC for up to 11 demands, for more it is necessary to divide the transport system into many zones and to do the optimization in any of them separately. In this case the optimal solution is not obtained, but a solution near to optimal.

5.2. Random solution

On the basis of experience with the heuristic solution of rack stackers and production schedules, an algorithm solving a selection of covering of a subgraph of transport demands with circles with a common point in the material store has been created and implemented. This suboptimal selection has been made from the set of repeated random selections. In a random selection, the biggest n-tuples of transport demands are selected ($0 < n < 5$) and for these n-tuples the best solution is chosen by searching all n permutations. The results of this optimization (percentage of shortening of transport routes in comparison to non-optimized variant) are given in Fig 3 for 5, 9 and 12 demands.

The decrease of lengths of transport for 5 demands was achieved after 10 attempts (5! is 120), for 9 and 12 demands after tens of attempts. The selections were made from 1000 attempts, but the decrease of lengths of transport routes was minimal.

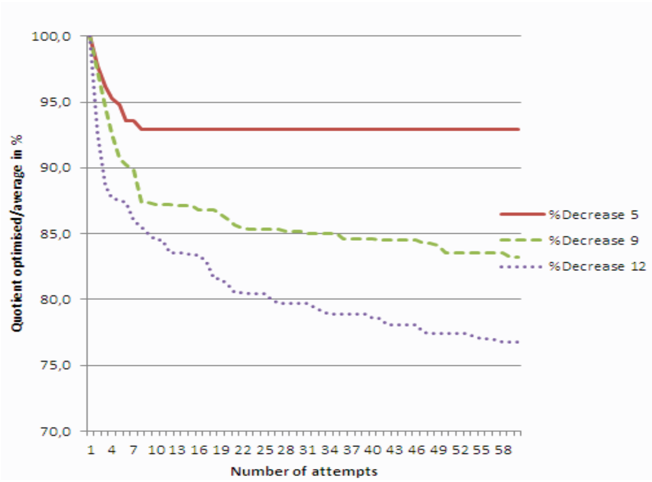

Fig. 3.Average improvement of transport routes for 5, 9 and 12 transport demands.

The average improvement was also examined in relation to the number of transport demands. At the same time the worst selection and deterministic selection of covering circles by choosing the nearest demand were examined. The results are shown in Fig 4.

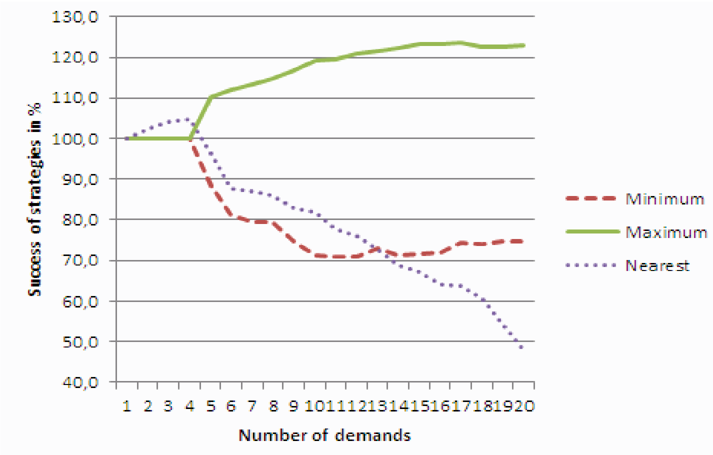

Fig. 4.Success of strategies (nearest demand, min and max random selection).

Whilst the deterministic algorithms of selection of the nearest demand for a small amount of demands show worse results than the optimized random selection, for a big number of demands its efficiency improves and becomes comparable and, in line with intuition, it is best when all served places demand services.

Experiments with sophisticated algorithms of simulation optimization have been carried out for comparison. These algorithms show a significantly greater sensitivity to the quality of input data and other influences such as:

- Acceleration and deceleration of trains
- Waiting for crossing and passing by
- Various times of connecting and disconnecting

6. Comparison with other strategies for optimizing supplies of production lines

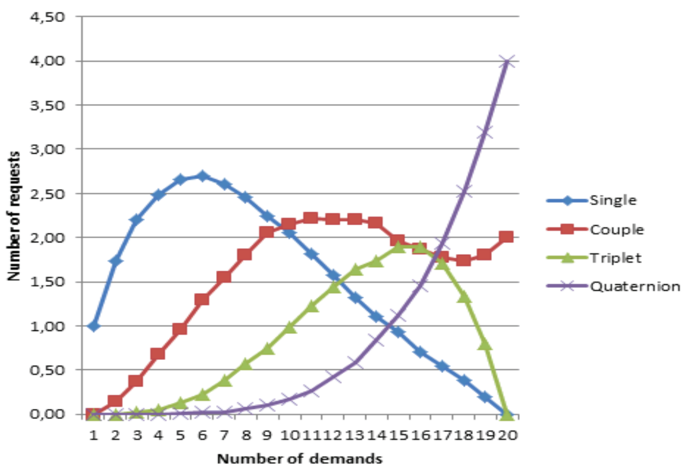

Fig. 5.Frequency of building of n-tuples.

Consider that demands for service in one assembly line could be:

- One in a line
- Two in a line
- Three in a line
- Four or more in a line

If there are four or more demands in a line no optimization is necessary. A triplet in one line could be completed with a single demand in another line. A couple in one line could be completed with a couple of another line or two single demands in different lines. The frequency of building these n-tuples is shown in Fig. 5

Using this strategy it is possible to obtain a fast good solution much better than using the strategy of choosing the nearest demand, but a little worse than using the repeated random selection.

7. Optimization of a stacker

Stackers can be used in automatic stores for storing and preserving materials and goods or in flexible manufacturing systems (FMS) as means of inter operation transport. The task of optimization is to sort and then process demands for transport in such way so that the sum of lengths of moves of an unloaded stacker (a stacker goes for a palette) is minimal in relation to the loaded moves (a stacker transports a palette).

The difference between these two uses is that it is possible to consider that input and output of palettes in a store is at one end of the racks and the transport demands are therefore asymmetric, whilst every workplace in FMS has its own input and output and therefore the transport demands could be equalized.

Four strategies of optimization have been used:

- FIFO (no optimization)
- All permutations (brutal force) – only up to 11 demands due to computing time
- Random permutations – the best of 1000 attempts
- Proximate demand (loading point) to current position of the stacker

7.1. Stacker in a FMS

The starts and ends of demands are generated with an equal probability for all places in racks. Results of optimization are in Fig. 6.

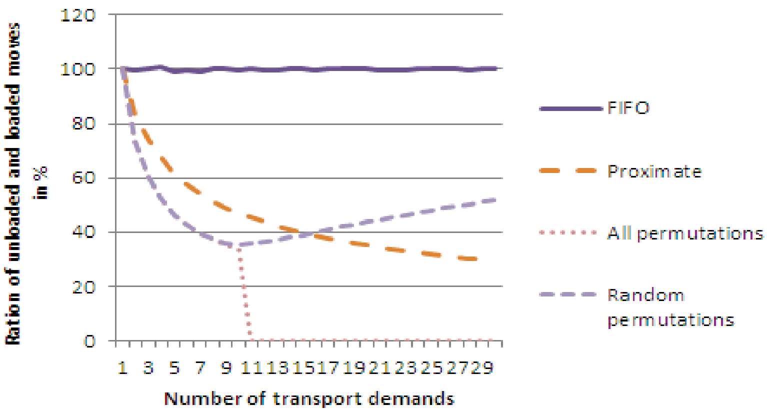

Fig. 6.Optimization of a stacker in a FMS.

The FIFO strategy does not depend on the number of transport demands. Repeated random permutations give the same results as all permutations up to 11 demands, the ratio of unloaded and loaded moves can be better than 40%, then the results grow a little worse, and for over 15 demands the proximate strategy is the best. Thus a combination of proximate (deterministic) and repeated random permutation (heuristic) is the best solution. This solution has been used in practice in some projects.

7.2. Stacker in a store

The starts and ends of demands are generated with an equal probability for all places in racks. Then randomly either start or end of a move is set to zero. This is a model of a store with input and output from one side of the store. Results of optimization are in Fig. 7.

It could be surprising that the FIFO strategy is self-optimizing with an increasing number of transport demands. This is because of the asymmetry of such a model. The proximate strategy is the worst all. The repeated random permutation can give better results than in a FMS model.

7.3. Stacker in a real production system

Other possibilities of optimization can improve the ratio between unloaded and loaded moves of a stacker:

- Trying to design a better layout of workplaces according to the routings and thus shorten the lengths of moves (in the project/design? of the workshop)
- Trying to find a place for storing a pallet near to the input (in the case of an overloaded transport) or near to the probable output (for under loaded transport) or somewhere between the input and output.

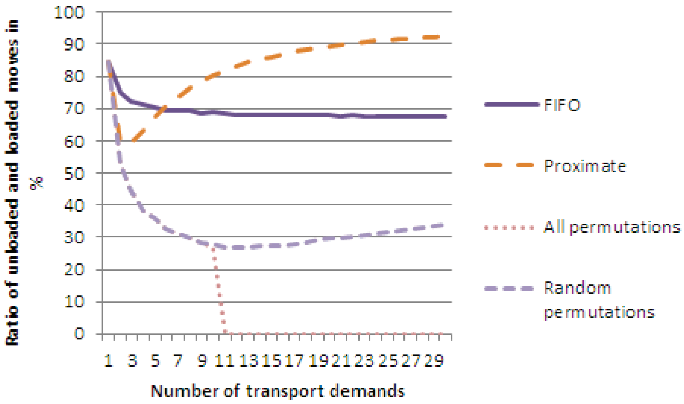

Fig. 7.Optimization of a stacker in a store.

8. Conclusion

The research carried out on an ad hoc proposed model proved the hypothesis that a dynamic optimization of train creation and specification of supply routes of trains can be made in real time using relatively simple methods which are not critically dependent on the accuracy of input data with good optimization results. Means of transportation and manpower can be saved in this way,and peaks of transport demands can be solved quicker.

The model presented here has been developed theoretically, but inspired by an actual production system model of an assembly line. Subsequent research will be based on the one hand on optimization of larger production systems with the hypothesis of division of the optimized system into two or more, and on the other hand on specification of accurate data of an actual production system and experiments leading to optimization of its supply demands.

The optimization of a stacker in a FMS or in a store has been presented for comparison.

Repeated random selections could be a good solution when optimization tasks are considered for NP-complete.

As has been shown above, some ad hoc deterministic strategies can also be used and compared with random selections.

Acknowledgements

The project presented in this article is supported by the project IGA ZČU SGS-2012-063. Results of the project OP VK n. CZ.1.07/2.3.00/09.0163 have been used.

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