Transactions on the Built Environment vol 18, © 1996 WIT Press, www.witpress.com, ISSN 1743-3509

Simulation of processes in a marshalling yard

P. Cenek
Department of Transportation Networks,
University of Transport and Communications,
Velký Diel, 010 26 Zilina, Slovakia

Abstract

An efficient control of processes in marshalling yards is an important part of railway cargo services. A model of a marshalling yard can be used as a support for a design of a yard, it can serve for planning tasks and can become a basis of an information system or a decision support system for a dispatcher. The article describes the model of a marshalling yard which is based on a general model of a transportation system but respects the special features of a railroad transport. The modelled processes include finding a path in a yard, dynamics of a motion of wagons in yard and problems of a simultaneous sorting. The article concentrates on technological processes in a yard which create only a part of a complete simulation model of a marshalling yard.

1 Introduction

Transportation systems can be modelled as a network of nodes and arcs between the nodes. Vehicles move along the arcs and transport some goods. Railroad transport is one of transportation modes and that is why a model of a general transportation system should be suitable to simulate processes in the railroad transport, too. This supposition is correct when global problems of a transport among railway stations in a network are to be solved. Unfortunately, there is a serious difference between a general transportation system and a railroad transport when the processes are investigated in more detail as in the case of simulation of a marshalling yard. The two most important differences are the impossibility of changing the order of wagons on a track (passing of wagons or trains on the same track) and the impossibility of making turns on switches. These two rules are to be respected in a simulation model.

The problem of creating a simulation model of technological processes in a marshalling yard can be divided into several steps. The very basic part of the model is the infrastructure of a yard. Wagons have to stand on tracks and also most of the processes (like a motion of wagons in a yard) are bound to the infrastructure. The second important part of the model are wagons and their motion in a yard. This process includes finding a path in a yard from the origin to the destination position of a wagon and then a calculation of dynamics of the motion. Also more complex processes can be modelled to create a decision support system for a dispatcher. One of the examples of such a task is an optimal plan of the simultaneous sorting.

A user friendly environment is a crucial part of a simulation model, too. A graphical output seems to be the only tool which would supply an operator with a relevant and easily understandable information. The mentioned problems will be discussed in the following paragraphs.

2 Model of infrastructure

A model of a railway infrastructure can be compared with the model of a general transportation system. A non-oriented graph can serve as a model of a general transportation system. The basic process then is a motion of elements among the nodes of the network. The situation in a railway transport is different already in this point. Wagons are not placed in the nodes but are distributed along the arcs and then moved among the arcs of the network.

One way of modelling such a system is to use a dual graph where nodes will represent tracks and arcs will describe the relation of a possible motion from a track to a neighbouring one. This graph can also inhibit the unwanted turns on switches. A disadvantage of this model is the difficulty of defining a precise position of wagons on a track, involving the length of a train in calculations and respecting the occupation of tracks when seeking a path in a yard.

Another possibility is to use the model of a transportation network. Nodes will represent the points where tracks join switches and arcs will stand for tracks between the nodes. A switch will thus be modelled as a pair of tracks with a special behaviour. If one of the tracks of a switch is occupied or used in a path, the other will have to be blocked automatically. This model of the infrastructure is easy to understand and also input data can be prepared without difficulties.

A very simple example of such a model is shown in Figure 1. For the same topology of tracks and switches a dual graph is shown in Figure 2.

Transactions on the Built Environment vol 18, © 1996 WIT Press, www.witpress.com, ISSN 1743-3509

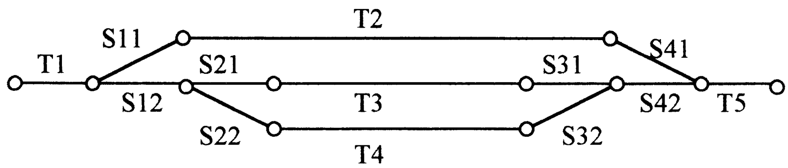

Figure 1. Simple layout of tracks and switches in a yard

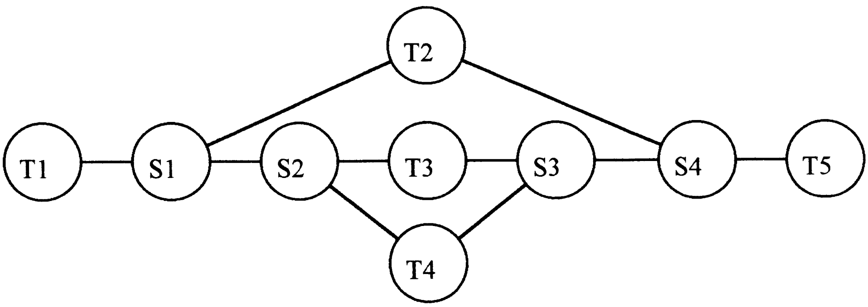

Figure 2 Dual graph representing the same layout of tracks and switches

3 Model of wagons

The motion of wagons is the most important process in a marshalling yard. As already mentioned, the process can be split into two steps. A free path from the origin to the destination position is to be found at first. Dynamics of the motion is to be estimated then using characteristics of the path and of moving wagons.

3.1 Finding a path

Finding the path in a transportation network is one of the very basic problems and there are many algorithms to solve it. Label set, label correct or threshold algorithms seem to be the best methods for finding a path between two points in a network. Nevertheless, the task to be solved in a railroad transport is to find a path between positions on tracks (it means between positions on arcs and not between nodes of a network). That is why the general algorithms can not be used directly but rather special methods have to be developed for a railroad transport.

The knowledge of an algorithm for finding a path in a network is useful and can be used in a design of the new algorithm. The first task is to change the problem from finding a path among arcs to finding a path among nodes. This is not really a problem because the path must go through one of the end points of the origin arc and of the destination arc. Thus we can add two more arcs from the start position to the ends of the origin arc and two arcs from the end points of the destination arc to the end position. The model is presented in Figure 3.

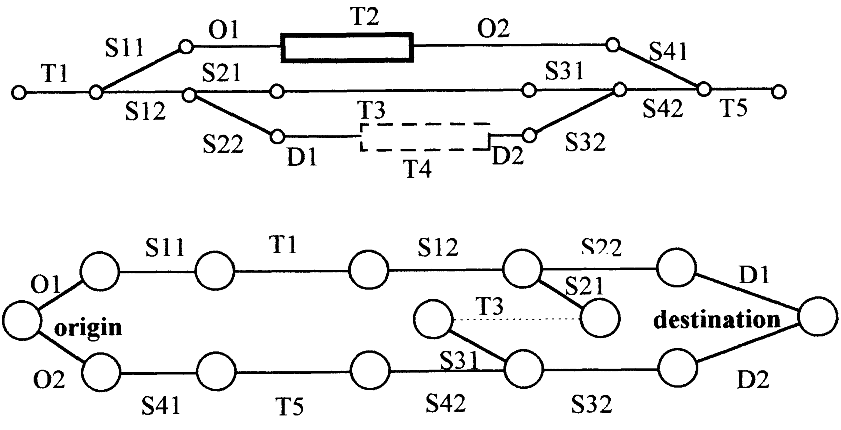

Figure 3 Alternative graph to find a path from the origin on T2 to the destination on T4

The origin position of a train is on the trackT2 and the destination on the track T4 (in a dashed line). The origin and destination tracks are then devided into two parts described as O1 and O2, D1 and D2. These new arcs are then added to a model for each task of finding a path between given origin and destination position. The modified model is shown in a lower part of the picture.

Transactions on the Built Environment vol 18, © 1996 WIT Press, www.witpress.com, ISSN 1743-3509

The other task is to model the turning manoeuvre on a switch. When the train enters a switch it must leave it on the other side before the switch can change the direction and the train can continue its path along the second track of the switch. The train must continue to run behind a switch by a distance which is equal to the length of the train. And that is why the problem of finding a path in a yard can not be solved only for a trackage in a yard but the information about a train must be taken into account as well.

Another information to be considered is a current occupation of tracks. The tracks can be filled with wagons or can be blocked when a route is set for a motion of a train along the track. In both cases this situation must be reflected in the algorithm for finding a path.

The algorithm for finding a path in a railroad network was implemented and included in a simulation model. The implementation is based on the idea of a label set method. It respects the conditions for turning the orientation of a motion on switches and the occupation of tracks by other wagons and moving trains. Under these conditions the path found is an optimal solution with regard to the distance or the time of a motion.

3.2 Dynamics of a motion

Dynamics of the motion is the second problem to be solved when designing the model of a wagon. There are different situations for which the dynamics of a motion are to be calculated. In any case we have to realise that there can be tens of wagons and trains moving independently in a yard. If the simulation program calculates all the changes in a real time, the simulation run will consume too much time calculating the motion using a precise dynamic model. That is why only approximate values are to be used instead. The values of a speed and travel time for a motion of a wagon have to be estimated in any case. That is why a dynamic model has to be derived and implemented. There are two distinct situations to be explored.

The first situation is a movement of a train in a yard. In this case a locomotive with its tractive force pulls a group of wagons with a known mass. The acceleration or deceleration of the motion is given mostly by the active force of a locomotive and all the resistances along the track are not so important. The basic dynamic model is as follows:

$$\mathbf{M}.\,\xi.\mathbf{a} = \mathbf{F}_t - \mathbf{R} - \mathbf{F}_b$$

where **M** - mass of a locomotive and wagons of a train [kg]

ξ - coefficient of a rotating mass [-]

a - acceleration or deceleration [m/s^2]

F_t - tractive force of a locomotive [N]

R - resistances from the slope of a track, rolling resistance etc. [N]

F_b - braking force of a locomotive [N]

The second case is a motion of a group of wagons from a hump in a sorting process. In this case there is no active force and only a weight of wagons on a slope accelerates their motion. A force of rail brakes could be used for a deceleration when the brakes are used in a yard. The speed of a free motion of wagons can vary greatly which is caused by different resistances like a resistance due to a slope, resistances in curves, switches, an aerodynamic resistance influenced by a wind with a given velocity and direction etc. All those forces are to be involved in the model.

The precise estimation of characteristics of a motion of wagons running from a hump is important for a design of a hump geometry, for considering positions of rail brakes, their dimensioning and defining the output velocity. The model was programmed as a separate module which serves for such a detailed investigation. It can be used as a basis for checking the humping speed for various combinations of wagon groups or for a real time control of the humping speed.

4 Simultaneous sorting

Formation of trains in a marshalling yard can be done with regard only to a destination of wagons or the trains can be fine sorted. In this case groups of wagons in a train are properly ordered in a sequence which corresponds to an ordered sequence of stations on a railway line. When the train is fine sorted for destinations on a line, the manipulation work in the stations on a line will be dramatically reduced, a danger of damages caused during manipulations will decrease and a minimum labour force will be needed for those manipulations. These are the advantages of forming a properly ordered group trains. The gains are to be paid for by an increased work load in a marshalling yard. The simultaneous sorting can be used to reduce the necessary extra work in a marshalling yard.

The simultaneous sorting can improve the sorting process if there are several trains to be fine sorted at the same time. The fine sorting can be organised in two ways. The most natural seems to be a method which sorts the wagons according to their main destination at first. In this way the wagons for a train are accumulated in one siding. The process of a fine sorting follows then. A simple example can show that quite a lot of manipulations are necessary to bring the ordered groups back to one siding and to compose a train by this approach.

Transactions on the Built Environment vol 18, © 1996 WIT Press, www.witpress.com, ISSN 1743-3509

A more effective way is the simultaneous sorting. With this method wagons are sorted according to their position in a train at first and only second phase of the sorting will accumulate wagons for a train in one siding. It means that at first all groups which will be on the first position in final trains will be sent to one siding, the second groups to another etc. In the second phase the wagons for the first groups will be sent to the proper sidings for trains, then the second and so on. The difference in favour of this sorting method is that after second phase of the sorting the trains are on the sidings ready to leave and no extra manipulations are necessary to compose the train.

This very simple method would eliminate unnecessary manipulation at the end of the sorting process. Nevertheless, this method would demand as many sidings as there is the maximum number of groups in a train plus the number of trains. So many tracks are usually not available and that is why a more complex scheme has to be applied. In this scheme several groups are sent in a siding during the first phase of sorting. In the second phase all wagons are pulled out from a siding and this siding can be then used for a formation of a train. The groups of wagons with lowest number will be sent to a final destination in a siding for train, while all other groups are sent to other sidings still occupied with groups of wagons. The sidings are much better used with this more complex sorting scheme so that for example 4 sidings are sufficient for fine sorting of 4 trains with up to 3, 4, 7 and 10 groups in a train.

More information on the method of simultaneous sorting has been presented by Potthof [1] or König [2], the principles of simultaneous sorting are described in [4], too. The implemented algorithm solves an optimal assignment of groups in a train to system numbers in a sorting scheme, decides on an optimal order of sorted trains and respect the number and capacity of used sidings. The simultaneus sorting was programmed separately and allows an optimal estimation of a sorting scheme for expected quantities of wagons.

5 Visualisation of processes

A graphical output of results of a simulation run is the basic method of a user - machine interface. The system will show the basic configuration of a yard, distribution of wagons in a yard and allows the animation of dynamic processes (motion of wagons) in a yard.

There are also several problems to be solved for the visualisation. The first task is to show a yard or a part of it on a screen. There is seemingly no problem to make a picture of a yard on a screen, unfortunately it is not so easy. The screen can distinguish approximately 1000 pixels in each direction while the resolution of a laser printer is in order of at least 300 dpi (dots per inch). It means that the same number of pixels which can be distinguished on a screen can be printed on only 10 centimetres space of paper while the format of a printed output can be measured in meters. It means that there is much less information capacity available on a screen than on a paper.

This disadvantage can be partly eliminated by a suitable windowing of a picture. The suitable choice of the window can be used only when the yard is situated straight and parallel to a co-ordinate axis. If the yard is oriented in another direction or is shaped in a curve, the windowing method will not work and more complex transformations will have to be used.

The visualisation of wagons and their motion in a yard is the next task. The basic condition on visualisation of wagons and trains is to place the wagon on a given track in a proper position and to respect the orientation of the track (the axis of a wagon should comply with the tangent of a track). The same principle should be used for the animation of a motion of wagons in a yard.

The animation is a very attractive but also very useful way of showing the traffic in a yard. As there are many wagons that can move independently in a yard a quasi parallel animation must be ensured for all simultaneously moving wagons. The speed of the animation should be independent of the number of moving wagons and independent of the performance of a computer on which the simulation will run. This can be done by reading the system time of a computer and estimating the time interval elapsed from the last drawing of a picture in the animation as

dTSyst = T1 - T0

where T1 is the current reading from the computer clock, T0 is the reading at the time when the last picture was drawn on a screen and dTSyst is the difference. The operator can set the scale of time TScale by which the elapsed time interval will be converted on an interval of simulation time dTSim by

dTSim = dTSyst * Tscale

Finally a distance travelled by a wagon during this period of a simulation time will be

dL = dTSim * v

for a constant speed motion or

dL = dTSim * (v + dTSim * a/2)

for a constant acceleration.

This method works well on different computers. The only problem can arise when the computer is slow or the number of simultaneously moving wagons is too high. The estimated step dL can be then too big so that wagons will not move smoothly and jerks will be visible.

6 Conclusions

Modelling and simulation of processes in a marshalling yard is a complex problem. The described model is concerned only with the infrastructure of a yard and technological processes which run on it. The simulation model must be completed by adding a control and managing part which would make necessary decisions on the feasibility and order of the activities to be performed. The decisions are to be taken by an operator or can be formalised and carried out automatically.

The clear separation of the model of technological processes from a model of a controlling subsystem seems to be advantageous as it reflects the reality well. The model of the technological part can be used independently as an information system or a decision support system for a marshalling yard's dispatcher.

The presented model complies as close as possible with a general transportation model and many designed procedures (especially the procedures for a description and visualisation of the infrastructure and animation of motions on a network) can be used in general applications.

The simulation model of processes in a marshalling yard was implemented and runs on a PC compatible computers. The model was programmed in Turbo PASCAL and uses the graphical output to show the current situation of a simulated system. Two parts of the model (dynamic calculations of a motion of wagons from a hump and method of simulatneous sorting) are already used in practice. The part of the model of the infrastructure, finding a path in a network, calculation of a motion of wagons and animation of processes in a yard is to be finished soon and will be integrated in a simulation model of a whole marshalling yard.

References

1 Potthof,G.: Verkehrsströmungslehre. Band 2 Betriebstechnik des Rangierens. Transpress Verlag, Berlin, 1962

2 König,H., Schaltegger,P.: Optimale Simultanformation von Nahgüterzügen in Rangierbahnhöfen. Kybernetik und Elektronik bei den Eisenbahnen, Vol.4 (1967), Nr.1, p.1

3 Cenek,P., Klima,V., Janáček,J.: Optimisation of transport and communication systems. Edičné stredisko VŠDS, Žilina, 1994. (in Czech)

Transactions on the Built Environment vol 18, © 1996 WIT Press, www.witpress.com, ISSN 1743-3509

4 Cenek,P.:A Model of a Simultaneous Train Sorting. In: Studies of the Faculty of Management Science, University of Transport and Communications, Žilina, No.4, 1995, pp.11 - 17

5 Klima,V., Kavička A., Sadloň Ľ.: MPE Model of Railway Yard. In: Proceedings of the 1995 European Simulation Multiconference, Prague, Society for Computer Simulation International, 1995, pp.374 - 378

6 Skýva,L., Cenek,P., Janáček,J.: Energy optimal control in transportation systems. NADAS, Prague, 1987 (in Czech)