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Simulation model of automated storage for high storage racks

I. Potrč, T. Lerher, M. Šraml, J. Kramberger

University of Maribor, Faculty of Mechanical Engineering
SI-2000, Smetanova 17, Slovenia

Automated storage and retrieval systems (AS/RS) have given industry the advantages of faster storages and retrieval of products, efficient utilization of storage space, high reliability and better control inventory, improved safety and decrease in damages of products. Therefore AS/RS which are used in manufacturing, warehousing and distribution centres have to be designed to provide quick response for storages and retrievals of products in order to keep the system operating efficiently. Heuristics travel time models for AS/RS with equal sized cells in height under randomized storage with one, two and three unit loads at the time are presented in this paper. The main contribution of proposed model is the implementation of a *x strategy* and determination of optimal values between throughput capacity and average travel time for five different storage racks and two different velocity profile.

1. INTRODUCTION

Automated storage and retrieval systems (AS/RS) are major material handling systems that have been widely used in automated factories and distribution centres. The basic components of the type of AS/RS are storage racks (S/R) machines, input/output (I/O) stations and interface conveyors [1].

Throughput capacity is influenced by AS/RS function, therefore multi load AS/RS have been developed to increase the throughput capacity of the system. In that case the S/R machine can storage up to three unit load at the time. Thus the throughput capacity of an AS/RS increases, as the number of unit loads increases, however average travel time decreases as the number of unit loads decreases. An analytical model for single and dual command cycle, proposed by Bozer and White [1], is first presented. Furthermore, a heuristics strategy for storage unit loads, named *x strategy* [2], has been discussed and implemented in our proposed model. The optimal values between throughput capacity and average travel times for storage have been determined and analysed at the end of the paper.

2. THE AS/RS ENVIRONMENT UNDER CONSIDERATION

2.1. Assumptions

Authors Bozer and White have developed expected cycle time expressions for AS/RS. They made the some assumptions [1], which were used as restrictions in the proposed model.

2.2. Notations

For deriving travel time models, the following notations are used: v_h is the speed of the S/R machine in the horizontal direction, v_v is the speed of the S/R machine in the vertical direction, H is the height of the rack in time unit, L is the length of the rack in time unit, $E_i(SC)$ is the expected travel time from/to zone i to/from the I/O point under single command, $E_{ij}(TB)$ is the expected interleaving travel time between zone i and zone j ($E_{ij}(TB) = E_{ji}(TB)$), $E_{ij}(DC)$ is the expected travel time for storage into zone i and retrieval from zone j under dual command.

2.3. Analytical travel time models under single and dual command cycles

While randomized storage is used (continuous, normalized rack face), the expected location for storage or retrieval is randomly distributed between 0 and 1 in the horizontal direction and 0 and b in the vertical direction. Due to the Tchebychev travel matrix [1] the normalized travel time between two random locations is given by the expression max (x_1-x_2 , y_1-y_2). Using this expression the following equations were developed:

- expected single command $E_i(SC)$ travel time

$$E(SC) = \left[\frac{1}{3}b^2 + 1\right]T \qquad (1)$$

- expected travel time between locations $E_{ij}(TB)$ for dual command cycle

$$E(TB) = \left[\frac{1}{3} + \frac{1}{6}b^2 - \frac{1}{30}b^3\right]T \qquad (2)$$

- expected dual command $E_{ij}(DC)$ travel time

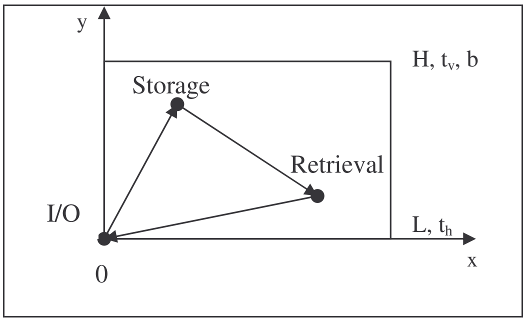

Figure 1. Illustration of AS/RS rack face

$$E(DC) = E(SC) + E(TB)$$

$$E(DC) = \left[\frac{4}{3} + \frac{1}{2}b^2 - \frac{1}{30}b^3\right]T \qquad (3)$$

Where t_h is time to reach the end of the rack from the I/O point, t_v is time to reach the top of the rack from the I/O point, T is normalization factor and b is rack shape factor.

3. SIMULATION MODEL

To facilitate the performance evaluation and comparison of the average travel time and throughput capacity, computer simulation was employed. Five different dimensions of storage racks, where I/O point is located at the lover left-hand corner of the rack were analysed. The S/R machine can move simultaneously in the horizontal and vertical direction with two different velocities profile (V1 or V2). In servicing the storage the first-come-first-served (FCFS) policy was performed. In the operation of a randomized storage system, when a unit load arrives for storage, a storage location is selected randomly. In the present study the S/R machine operate under *x strategy* [2] (see figure 2). Implemented *x strategy* with three unit loads is presented in figure 2. Every unit load is given at the beginning by the computer the exact position in x, y and z location of the storage rack. Unit load that has the lowest value in the *x position* has been storage first by the S/R machine and then other unit loads. In principal the equation *x1* < *x2* < *x3* must prevail and we can gain on lowest travel times.

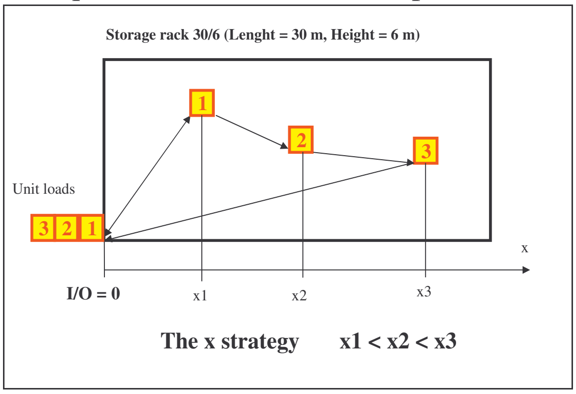

Figure 2. Storage with three unit loads

The travel time is calculated using following equation:

$$t = (t_{dl} + t_{rt}) \cdot 3 - t_p, \qquad (4)$$

where:

$$\bar{t} = \frac{\sum_{1}^{n} t}{n}$$

is average travel time, t_{dl} is time to deliver, t_{rt} is time to retrieve, t_p is pickup time, n is number of unit loads.

3.1. Velocity profile V1 and V2

Two of the velocity profiles were used in the simulation study, which were taken from Vidovics [3]:

Velocity profile V1 (slow)

$v_x = 3$ m/s $v_y = 1.5$ m/s
$a_x = +1.2$ m/s^2 $a_y = +1.5$ m/s^2
$a_x = -1.2$ m/s^2 $a_y = -1.5$ m/s^2

Velocity profile V2 (fast)

$v_x = 4$ m/s $v_y = 4$ m/s
$a_x = +3$ m/s^2 $a_y = +3$ m/s^2
$a_x = -3$ m/s^2 $a_y = -3$ m/s^2

4. ANALYSES OF PERFORMANCE RESULTS

The simulation results of the average travel time obtained for each five different storage racks, when the A/S machine operates under two different velocity profiles are shown in the figures 3 and 4.

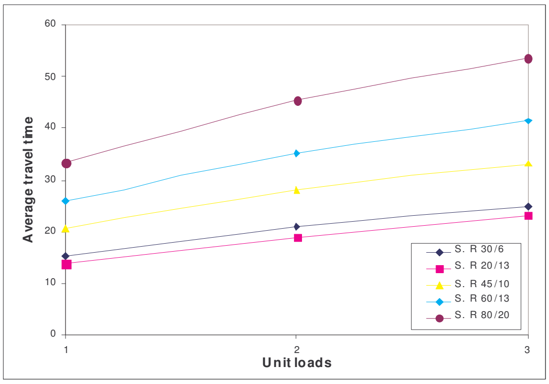

Figure 3. The comparison of average travel times for five different storage racks with velocity profile V1 (slow)

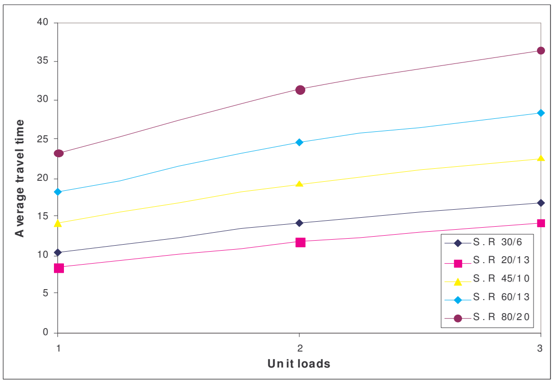

Figure 4. The comparison of average travel times for five different storage racks with velocity profile V2 (fast)

Examining the system performance (see figure 3), it is obvious that average travel time is lowest in the storage rack with dimensions L = 20, H = 13 m and the highest average travel time is in the storage rack L = 80, H = 20 m. The most important fact is that the average travel time increases with the number of unit loads and is the highest when the S/R machine moves three unit loads at the time. Due to the highest average travel times we gain on the throughput capacity, which is the highest when the S/R machine moves more unit load at the time. Optimal proportion between the average travel time and the throughput capacity can be found between the curves S. R 30/6 and S. R 80/20.

5. CONCLUSION

New model for storage policy, based on the *x strategy* for five different storage racks and two different velocity profiles, by means of computer simulation, has been presented in this paper. Main conclusion is, that if the S/R machine operates under *x strategy* with two or three unit loads the higher throughput capacity is achieved, compared with the one unit load. Due to the higher values of throughput capacity the larger average travel times are expected. The optimal ratio between throughput capacity and the average travel time depends on the proper design of the storage rack and appropriate storage policies.

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