Design, Development and Analysis of Automated Storage and Retrieval System with Single and Dual Command Dispatching using MATLAB

M. Aslam, Farrukh, A. R. Gardezi and Nasir Hayat

Abstract—Automated material handling is given prime importance in the semi automated and automated facilities since it provides solution to the gigantic problems related to inventory and also support the latest philosophies like just in time production JIT and lean production. Automated storage and retrieval system is an antidote (if designed properly) to the facility sufferings like getting the right material , materials getting perished, long cycle times or many other similar kind of problems. A working model of automated storage and retrieval system (AS/RS) is designed and developed under the design parameters specified by Material Handling Industry of America (MHIA). Later on analysis was carried out to calculate the throughput and size of the machine. The possible implementation of this technology in local scenario is also discussed in this paper.

Keywords—Automated storage and retrieval system (AS/RS), Material handling, Computer integrated manufacturing (CIM), Light dependent resistor (LDR)

I. INTRODUCTION

MATERIAL storage systems are used to store a variety of materials like raw materials, finished goods, tooling, spare parts, etc. An automated storage/retrieval system can be defined as *a storage system that performs storage and retrieval operations with speed and accuracy under a defined degree of automation* [1]. The performance of any manufacturing firm depends largely on its material handling and storage system. The vertical storage systems are important in the sense because less floor space is required to store a large number of goods. Material storage can be performed manually but the automated methods for storing and retrieving materials are more efficient and these are integral part of computer integrated manufacturing (CIM).

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The capacity of the designed automated storage and retrieval system to store various parts is fifteen. The developed Pallet Rack AS/RS system consists of five rows and three columns to store parts in vertical direction to utilize the floor space efficiently. The designed AS/RS also works with dual command cycle in which it performs the storage and retrieval operations in same cycle. The designed AS/RS system has computerized data base to store the position of materials in all storage locations and also it can determine whether a particular storage location is full or empty. When a command is dispatched for the storage or retrieval of an item to a particular location the system first checks the status of the location in the data base either it is filled or empty. The storage retrieval machine will be actuated after determining this status to perform the assigned task. Random storage location strategy is employed in this system and it can store unit load of certain designed dimensions.

The improved inventory management, space efficiency, reduced labor costs and reduced costs of loss by theft and misplacing are some of the advantages of automated storage and retrieval system through which the efficiency of material handling and inventory control can be enhanced [2].

Material handling operations are labor intensive and are of repetitive nature. Although very few handling systems are completely automated, the automation, control and mechanization play a significant role in designing and operating effective and efficient handling systems. Automated storage/retrieval (AS/R) systems, carousels/rotary racks, automated guided vehicles (AGV) systems, and robotic systems are some of the most commonly used material handling systems in manufacturing industries [3].

Material handling systems are the backbone of computer integrated manufacturing systems and flexible manufacturing systems where the assignment of storage and retrieval of parts is based on the needs of manufacturing operations which can increase not only the performance of the automated storage/retrieval system (AS/RS) but also the performance of the production system [2].

Picking cart, tote picking, man-onboard system, various kinds of truck are some of the equipments used in automated storage and retrieval systems and most of these can enable the racks to conduct only up-and-down conveyance at the fixed

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range of track, but they cannot move to another aisle [4].

A typical AS/RS is composed of storage racks, storage/retrieval (S/R) machines and pickup/drop-off (P/D) stations. Based on volume of inventory level and size several types of AS/RS are unit-load, mini-load, man on-board, deep-lane, automated item-retrieval system and flow rack systems [5]. Dual commands dispatching of a class-based unit-load automated storage and retrieval system using multi-pass simulation with generic algorithm has been studied in reference [6] .The adoption of automated storage and retrieval system in flexible manufacturing system with optimal random storage location strategy is studied in reference [7].

Ref. [8] Studied automated guided vehicle loop problem in automated storage/ retrieval system under FCFS and FEFS rules. Genetic algorithm used for the dynamic selection of sequencing rules for a class based unit load automated storage and retrieval system [9].

The terms defined below are taken from reference [1].

Storage capacity: It can be measured as the total volumetric space available or the total number of storage compartments available in the system for items or loads.

Storage density: It is the volumetric space available for actual storage relative to total volumetric space in the storage facility.

Unit load: It is simply the mass that is to be moved or otherwise handled at one time.

Single command cycle: In this cycle storage or retrieval transactions alone are performed.

Dual command cycle: In this cycle the storage and retrieval transactions are performed in one cycle.

Randomized storage: In this storage system the items are storage are at any available location.

Dedicated storage: In this storage system items are assigned to specific locations.

II. AS/RS DESIGN

The AS/RS under study is a single aisle and one sided rack system served by a single S/R machine. The pickup and delivery station (P/D) is located at the bottom right corner of the aisle and accessed by the S/R machine.

In order to illustrate the ideas proposed in this paper, an AS/RS is considered with the following assumptions:

(1) The system is considered for symmetrical unit loads with identical items.
(2) The items are selected for storage according to first come first serve (FCFS) rule.
(3) The items are allocated to storage location according to randomized storage strategy.
(4) There are 3 rows and 5 columns of equally sized storage locations in a rack. Each location has height of 4 inches, width 12 inches and length of 9 inches.
(5) Each storage location is specified for single unit load.
(6) Acceleration and declaration effects are neglected in the calculations.

The system is designed with the following specifications:

Sizes of AS/RS
Capacity = 5x3 = 15 storage compartments
Width = 2(10 + 2) = 24 inches = 61 cm
Length = 3(8 +1) = 27 inches = 69 cm
Height = 5(3.5 + .5)   = 20 inches = 51 cm
Unit load Dimensions
Width = 10 inches
Length = 8 inches
Height = 3.5 inches

Pro-E wildfire 3 is used for the 3D modeling of AS/RS with above specifications. The front, side, top views of the models are shown in Fig. 1(a, b and c) respectively. 3D model is shown in Fig. 2 in which the S/R machine is at the initial position (bottom right corner) and a unit load is placed on it to be stored at empty storage location.
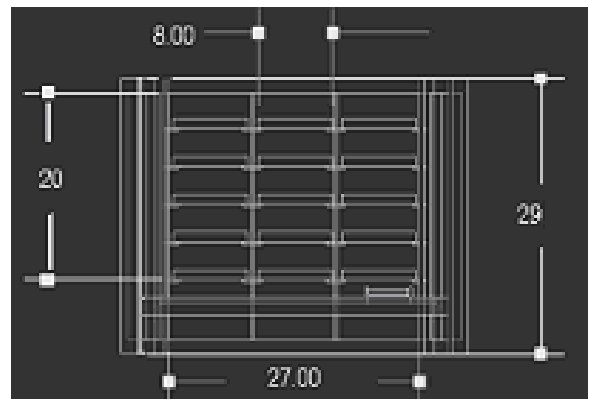
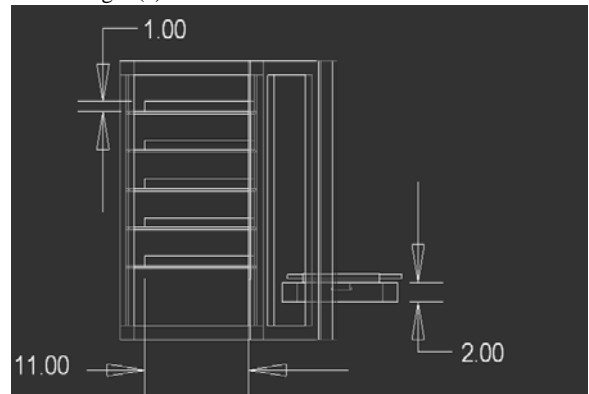

Fig. 1(a) Front view of 3D model of AS/RS
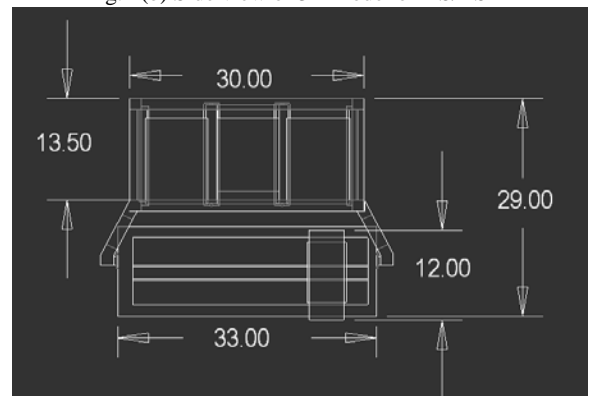

Fig. 1(b) Side view of 3D model of AS/RS

Fig. 1(c) Top view of 3D model of AS/RS

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TABLE I
NOTATIONS USED

X	Depth of unit load
Y	Width of unit load
Z	Height of unit load
Tcs	Cycle time for single command cycle (min/cycle)
L	Length of AS/RS rack structure (m, ft)
Vy	Velocity of S/R machine along the length (m/min, ft/min)
Vz	Velocity of S/R machine along the vertical direction (m/min, ft/min)
Tpd	Pickup and deposit time (minute)
Tcd	Cycle time for dual command cycle
Rcs	Number of single command cycles performed per hour
Rcd	Number of dual command cycles performed per hour
Ny	Number of load compartments along the length of aisle
Nz	Number of load compartments along the height of aisle

III. AS/RS DEVELOPMENT

Considering the above specification the AS/RS system is developed with minimum cost. The cost of this system is thirty times less than the available AS/RS systems in market. It is made to support the local manufacturing industries in Pakistan.

The AS/RS is the floor mounted automated storage and retrieval system containing 15 storage cells. The system dedicated Cartesian robot transfers parts between storage cells and conveyer pallets stopped at the AS/RS station.
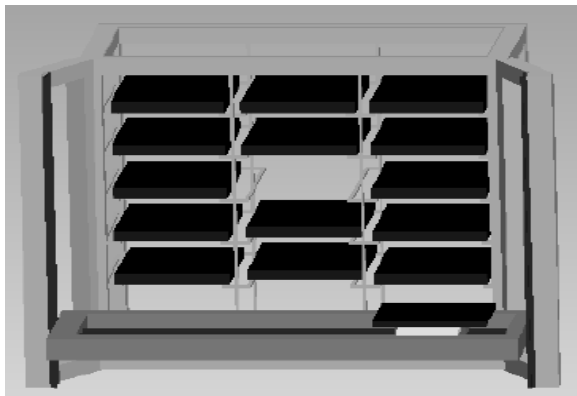

Fig. 2 3D model of AS/RS

The AS/RS is controlled by computer integration through parallel port. A floor-mounted automated storage and retrieval system that contains 15 storage cells arranged in 5x3 arrays. Storage cell in the AS/RS contains templates (either empty or loaded with parts).The AS/RS will store these templates as unit load containing raw materials prior to production as well as finished products. *Templates are the plastic trays which can hold various types of parts.* They allow parts to be transported on the conveyer. A template contains a matrix of holes in which pins are placed to fit the dimensions of a part. Each arrangement of pins defines the unique template type. Each part may actually be held by assigned template.

The AS/RS system is a single aisle steel pallet rack with fifteen storage locations. The size of each location is (12 x 9 x 4) inch. It can store a unit load of (10 x 8 x 3.5) inch. The developed AS/RS system is shown in Fig. 3. The arrows shown in figure 3 indicate rack, S/R machine and unit load.
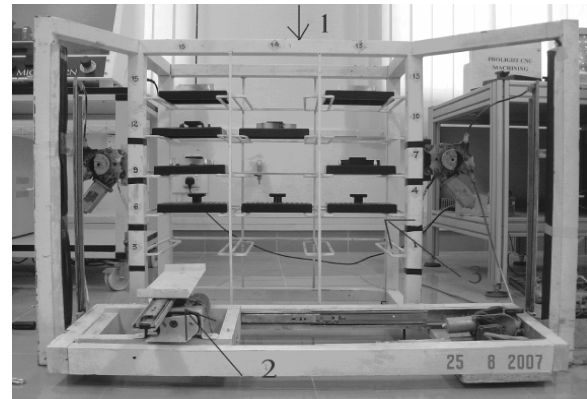

Fig. 3 Developed AS/RS structure

It can be integrated with the computer via parallel port and can also be controlled by microcontroller. The function of electronic devices used in this system is described with the help of circuitry diagram shown in Fig. 4. Seven-segment display is used to display the entered number for the escape of user entry mistake. 5x5 LED matrix is used to show the position of the S/R in terms of x, y coordinates in real time.
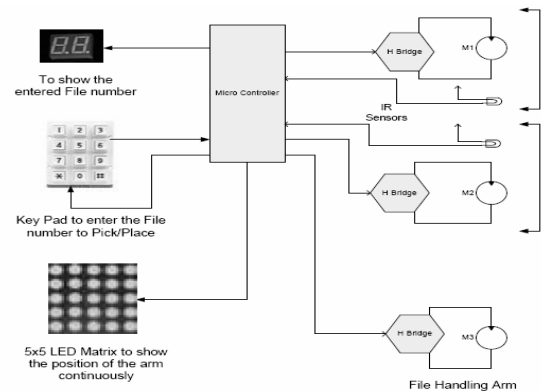

Fig. 4 3D model of AS/RS

LDR is used that differentiate the changes in the intensity of light emitting diode (LED) reflected from the white bar. Intensity is changed when sensor passes over the black tape. H-Bridge will ensure the movement of motors (sliders) clockwise and counter clockwise as required switching quickly. For this purpose an IC L298 Dual Bridge for single motor deriving up to maximum 4 amps is used for reliability. Central Unit (Brain) of embedded system to recognize signal from key pad and IR Sensors and deciding movements of sliders according to program burned and indicating status.

IV. AS/RS WORKING

The positions of the different storage locations in AS/RS are shown in the Fig. 5.

Initial position of S/R machine as shown in figure 4 takes the position variables y=0 and x=0.

Follow the steps given below to either retrieve or store the unit load at desired location.

- User is just required to click on the desired location.

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- Press enter.
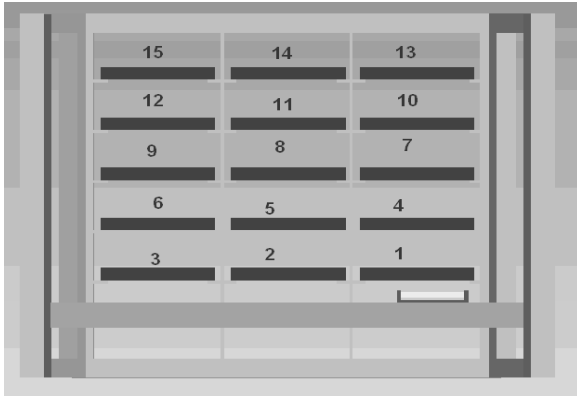- Press store or retrieve as the requirement may be.

Fig. 5 Layout of AS/RS

Internally, in the software entered number will be decoded into x and y coordinates i.e. y=3 and x=2 vertical slider will move up and y-variable will updated as IR sensor will interrupted by the shelves (Row) rod and will be stopped along the 3rd row according to matched condition. Similarly, horizontal slider will move right and position variable will be incremented by the interruption of the IR sensor due to vertical rods. Pan 2 will be stopped as prescribed condition i.e. x=2 is matched. The status of the position of the Handing Arm will be indicated by 5x3 LED matrix display be single LED ON at a time. After meeting the condition of position variables x and y prescribed box number pick and drop arm will move in, to unload the unit load. Then reverse procedure will be adopted to get the unit load at the P/D Station.

Run the exe file of the MATLAB program (MATLAB run time needs to be installed in the computer). The graphic user interface (GUI) appears on the screen as shown in Fig. 6(a).
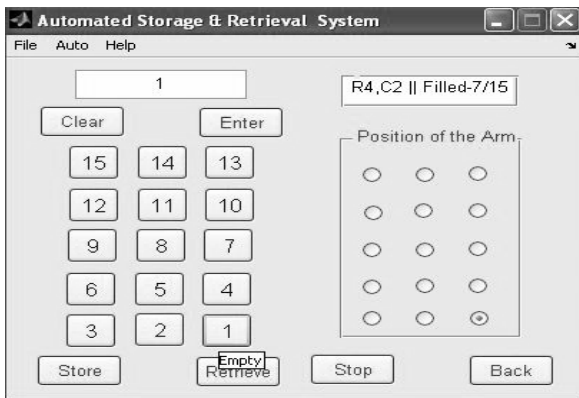

Fig. 6(a) Graphical user interface

Place the cursor on the required number where transaction is to be made, if it is empty then it will be notified as shown in the figure, if wrong entry is done the error is generated as shown in Fig 6(b).
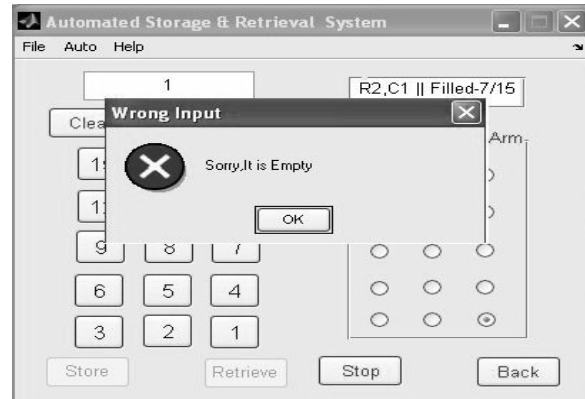

Fig. 6(b) Graphical user interface

V. Engineering Analysis

A transaction involves depositing a load into storage or retrieving a load from storage. Either one of these transactions alone is accomplished in a single command cycle. A dual command cycle accomplishes both transaction types in one cycle [1].

The observed S/R machine velocities used for the calculations are as follows:

Horizontal movement velocity = 10cm/s
Vertical movement velocity = 5cm/s
Time for pick drop pan = 3 seconds

The maximum horizontal and vertical distances traveled by S/R machine from initial to farthest positions are 46cm and 41cm respectively.

The equations used in the analysis are borrowed from [1]. The S/R machine moves either in horizontal or vertical direction at one time so the equations are modified according to current scenario.

$$T_{cs} = 2\max\left\{\frac{0.5L}{v_y} + \frac{0.5H}{v_z}\right\} + 2T_{pd} \tag{1}$$

$$T_{cs} = \max\left\{\frac{L}{v_y} + \frac{H}{v_z}\right\} + 2T_{pd} \tag{2}$$

$$T_{cs} = 2\max\left\{\frac{0.75L}{v_y} + \frac{0.75H}{v_z}\right\} + 4T_{pd} \tag{3}$$

$$T_{cs} = \max\left\{\frac{1.5L}{v_y} + \frac{1.5H}{v_z}\right\} + 4T_{pd} \tag{4}$$

The analytical results are presented in the Table-II.

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TABLE II
RESULT COMPARISON FOR SINGLE COMMAND CYCLE

Performance Measures	For Centre Location	For Extreme Location
Analytical Results		
T_{cs}	16	27
R_t	225	133
Experimental Results		
T_{cs}	18	29
R_t	200	124
Percent Error		
T_{cs}	12.5	7.4

In Dual command cycle, the load is stored at central location and retrieved from the farthest location. The transaction time was computed as 31.5sec and the actual transaction time is 34sec. The percent error is 7.94.

VI. CONCLUSIONS

In this paper, a cost effective single aisle AS/RS system has been developed with fifteen storage locations (3x5) and the size of each location is 10" x 8" x 3.5" The algorithm is formulated using MATLAB 6.0 and database regarding the status of storage location (either filled or empty) is stored in its own operating system. In the original design the S/R machine is located at the bottom right corner of the system as its initial position however the efficiency can be further improved by keeping the S/R machine at central bottom position. The results of the experiments show that the efficiency can be enhanced by minimizing the delays of actuating systems.

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