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A Review on Automated Storage and Retrieval System

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Abstract - *Automated Storage and Retrieval Systems are commonly used to store and retrieve variety of products in warehousing, distribution centers and now a days in service environment also. This paper presents a detailed study of AS/RS which focuses on classification, physical design of system, selection of control policies best suitable for the requirements. A Majority of literature presents travel time expressions of unit load systems with various storage allocations, dwell point locations, sequencing rules. Still there are some areas which are growing to develop within recent years to fulfill increasing demands. Present study and scenarios are discussed to design and implement new AS/RS in Library environment.*

Key Words: Automated Storage and Retrieval System, Physical Design, Control Policy.

1. INTRODUCTION

Automated material handling process has been used by business enterprises for many years. Automated Storage and Retrieval System (AS/RS) is material management system used to transport materials within manufacturing environment over a specified period of time under defined degree of automation [6]. The primary objective of a material handling system is to safely deliver the material in the right amount to the desired destination at the right time and at minimum cost. Fully automated system eliminates human aids while performing storage, removal or transfer of material. All operations are performed with the help of machines and human work is to control or to observe machine storage and retrieval operations. It supports storage of variety of products such as raw products, work-in- process jobs and finished one also. It is used over main application areas such as unit load storage and handling, order picking and work-in-process storage system [6].

2. AS/RS components and Terminology

It consists of storage racks, storage /retrieval machine(S/R machine), Input-output stations (I/O station). Pick up and Deposit operations to I/O station may be manually operated or performed by machine such as Conveyor, Auto guided Vehicle, Pick and Place Robot, etc. Location of each storage module is specified over rack. Storage modules are of standard size ensures smooth handling of load by S/R machine. Computer control system and programmable logic controllers are used to determine the required location and guide the S/R machine to its destination [6].Figure 1 shows schematic of AS/RS which described as:

1. Storage Rack: Structured rack provided with storage spaces, bays, rows.
2. Storage Space: 3-D space in rack utilized to store unite load.
3. Bay: Total height of Storage rack from base floor to the top of rack.
4. Row: Series of bays placed one by one aside.
5. Aisle: Space provided between two rows of AS/RS where S/R machine can travel.
6. S/R Machine: Material handling system carrying load across the structure in horizontal and vertical direction.
7. Storage Module: Unit load carrying inventory items. Modules are generally made of standard size.
8. Input–Output Station: Pick up and deposit location where load is being transported generally located at the end of aisle. Pick up and deposit can be at a single station or may be at separate locations as per requirement.

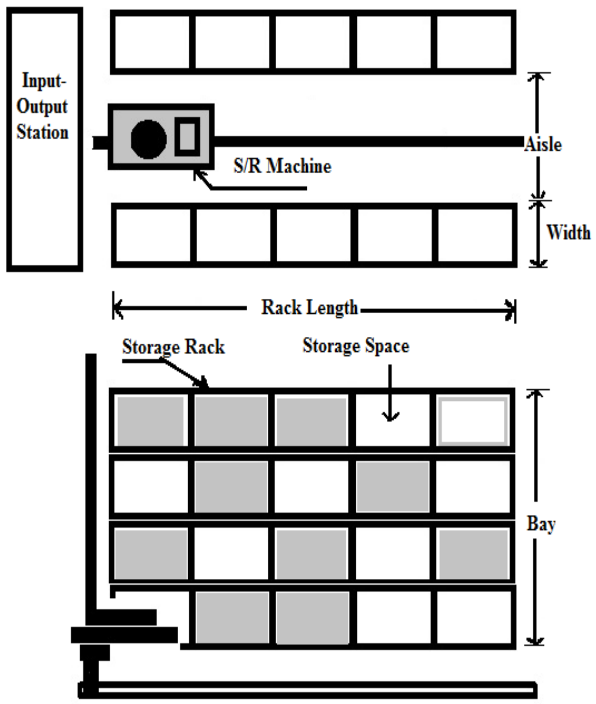

Fig -1: Schematic diagram of AS/RS

3. Classification of AS/RS

1. According to Structure of Rack System [6]:

A. *Pallet Rack*: Unit loads or pallets are stored over horizontal beam.

B. *Portable Racks*: Portable rack frames holds unit load which are stacked one over another.

C. *Cantilever Racks*: Same as pallet rack only horizontal beams are cantilevered from vertical centered frame used to store long bars, rods, pipes.

D. *Drive through racks*: Aisles are open at each end provides access to vertical rails or forklift trucks.

E. *Flow through Racks*: long conveyor tracks carry unit loads. Unit loads are loaded from one side and moved from another side of racks.

2. According to types of racks:

A. *Stationary Racks*: Location of racks and storage spaces are fixed.

a) *Single Deep*: Only one unit load is stored at each storage space which is commonly preferred [3].

b) *Dual Deep*: Two loads are stored one facing another at each space. Useful when less variety of unit loads are provided [3].

B. Movable rack System:

a) *Mobile Racks*: Racks can be moved over guided rail track.[1]

b) Carousel System: Rotary shelves or stacks are moved across overhead conveyers or long oval rail system. Crane is used to transfer load to the system. Stacks may move vertical or horizontal direction. Used to store small or medium sized items [6].

3. According to usage of crane:

A. Movement of Crane:

a) *Aisle Captive*: Each aisle has one S/R machine.

b) *Aisle Changing*: Few cranes are provided than number of aisles able to change aisle.

B. Number of Shuttles:

a) *Single Shuttle*: S/R machine handles only one unit load at a time [3].

b) *Multi Shuttle*: S/R machine handles two or more unit loads at a time [3].

4. According to Method of Handling a load:

A. *Unit Load*: Entire unit load is carried by forklift trucks, conveyors, etc. from the other location. Unit load then stored and retrieved from AS/RS after certain interval of time. [1, 2, 4, 8, 10, 11, 13, 14, 17,18]

B. *Mini load System*: System stores small loads in bins or drawers. Total storage volume is less than unit load system.[9]

C. *Man-on-board*: Instead of retrieving entire load automatically man ride over S/R machine and pick only one item from unit load.[6]

D. *End of aisle system*: Picker located at the end of aisle can pick required few items from unit load and S/R crane restore the unit load to the rack.[15]

4. Design of AS/RS

4.1 Physical Design of System:

Physical system defines configuration and dimensions of the system. System can be configured based upon previous available data, space availability and requirement, available budget and required throughput from system. System can be configured as [3]:

A. Load size to be handled

B. Size parameters such as number of rows, number of bays in each row, individual storage space dimensions, number of storage spaces required.

C. Number of aisles, Rack height and Length of Rack, Number of S/R machine required.

D. Selection of storage spaces such as Equal sized or modular to face variable dimensions.

E. Location of input-output station.

4.2 Selection of Control Policy:

A. Selection of storage allocation policy:

It defines position to assign storage location for the given product.

a) Selection of type of storage:

I. *Random Storage*: Storage at any vacant place.

II. *Dedicated Storage*: Storage of item at its predefined place. It requires fixed number of items. Each item have own space which cannot be shared with another.

C	C	C
B	B	C
A	B	C

Figure 2: Class Based Storage Allocation

III. *Class-based Storage*: Items can be bifurcated into more active and less active stock and then more active stock is located near input–output station than less active.

Figure 2 shows class based storage arrangement where A, B, C are three different classes containing 3 different products allocated from left to right direction of rack according to frequency of their demand.

b)Define storage rules [10]:

I. *Random Storage Allocation*: Storage at any random vacant space. Each vacant place has equal chance to get selected.

II. *Closet open Storage allocation*: Check vacant place at lower level first, if not then go to next level or row.

III. *Turnover Based Storage Allocation*: Create the zones of items in order of increasing demand of stock. Items frequently demanded are placed near input-output location. But any addition or removal of item in list results repositioning of item every time.

IV. *Class Based Storage Allocation*: Total storage locations are grouped into number of classes and arranged as per frequency of frequent demand. Random storage is used to store items in a class.

V. *Allocation for shortest processing time*: More active stock placed near input-output station to minimize processing time.

B. Selection of command cycle [3]:

Command cycle enlists number of storage or retrieval operations performed in each cycle.

a) *Single Command Cycle*: Each cycle performs only one operation at a time such as either storage or retrieval. After completion of each cycle S/R machine moves empty towards dwell point.

b) *Dual Command Cycle*: Each cycle performs storage and retrieval operation sequentially and goes idle at dwell point.

c) *Four Command Cycle*: Four operations (two storage and two retrieval) are performed per cycle. Generally adopted by multi shuttle S/R machine.

C. Selection of Dwell point Policy [19]:

Dwell point is the location where S/R machine remains idle. Dwell point strategies are used to locate S/R machine after completion of storage or retrieval operation.

a) Return back to input-output station.

b) Remains idle at storage location after completion of operation.

c) Travels to mid-point location of rack.

d) Travels to I/O station after completion of entire cycle (Dual Command Cycle).

Various travel time models are derived for selected dwell point policy which defines mathematical expression for expected travel time as dwell point location have an effect over the entire travel run.

D. Batching of Orders:

Instead of performing an individual operation at a time storage or retrieval operations are listed and then grouped into batch to reduce total travel time of S/R machine. Batching of orders reduces travel run by machine compared to individual operation. Batch size can be determined either for short processing time or capacity of S/R machine to perform number of operations in given time to raise throughput of system.

Order picking rules: Storage or retrieval requests are grouped or sequenced in batch of orders according to rules such as [3],

a) First come first serve.
b) Last come first serve.
c) Priority based orders first.
d) Random order picking.

E. Performance Measures:

Performance measures [3] varies according to selection of control policies, some of them are described as follows

a) Total time for storage or retrieval.
b) Waiting time for storage.
c) Waiting time for retrieval.
d) Total Productive travel time.
e) Total time required to perform batch of orders or certain requests.
f) Average travel time per request.
g) No. of requests/ operations handled per time period.
h) No. of requests to be stored or retrieved.

5. Literature Summary:

Various authors have adopted different approaches to design and to analyze performance parameters regarding Automated Storage and Retrieval System. While designing AS/RS, Unit load [1, 2, 4, 8, 10, 11, 13,14,17,18] is selected widely than others. Mini load system [9] where small loads are stored in bins or drawers. Unit load with split platforms [5, 6, 16] have used with two platforms-horizontal and vertical moves independently across their intended directions. Average expected travel run is reduced by using Split platforms.[16] Some cases Autonomous vehicle [11] or Tower crane [14] are used instead of Stacker crane(S/R machine). Autonomous Vehicle Technology (AVS) [11] provides vehicle to travel over guided rail and lift to travel vertically to reach the load in the rack. The results by evaluating travel time expression for such system shows saving in cost as per utility comparison of AVS and AS/RS.

Sr. No.	Author	Study Approach	Performance measure	Type of AS/RS	System Configuration				Control Policy			
					Type of Storage Rack	Number of S/R machines	Number of Aisles	Number of Input - Output Locations	Storage Allocation	Command Cycle	Batching And Sequencing of Orders	Dwell Point Policy
1	Amine Hakim Guezzen et.al.	Analytical with computer simulation	Travel time analysis	Unit load	Mobile Rack System	Single	Multi aisle	Single	Random Storage	Single Command Cycle	---	---
2	Banu Y. Ekren et.al.	Simulation	Regression analysis for rack configuration	Unit load	Continuous rectangular Pallet rack	Multiple	Multi aisle	Single	Random Storage	---	First come first serve	Stay idle after storage /retrieval
3	Guiliang Zhou et.al.	Simulation	Storage location optimization	---	Continuous rectangular Pallet rack	Multiple	Multi aisle	Multiple	Light upper Heavy lower layer	---	First come first serve	---
4	M. Aslam et.al.	Matlab Simulation	Travel time analysis	Unit load	Continuous rectangular Pallet rack	Single	Single aisle	Single	Random Storage	Single and Dual Command Cycle	First come first serve	---
5	M.R. Vasili et.al.	Analytical with computer simulation	Comparison of Travel time analysis	Unit load with split-platform S/R machine	Continuous rectangular Pallet rack	Single	Single aisle	Two	Random Storage	Single command cycle	---	Return to middle point and Return to start point
6	Mohammadreza Vasili et.al.	Analytical with computer simulation	Travel time analysis	Unit load with split-platform S/R machine	Continuous rectangular Pallet rack	Single	Single aisle	Two	Random Storage	Single command cycle	First come first serve	Return to middle point
7	Mohammadreza Vasili et.al.	Monte Carlo Simulation	Travel time analysis	Mini Load	Open rack	Single	---	Multiple	Random Storage	Single Command Cycle	First come first serve	---
8	N. Jawahar et.al.	Analytical with computer simulation	Heuristics and genetic algorithms for performance improvement	Unit load	Continuous rectangular Pallet rack	Single	Single aisle	Single	Random Storage	Single command cycle	---	---
9	Po-Hsun Kuo et.al.	Computer simulation	Comparison of Travel time analysis of AVS and AS/RS	Unit load with Autonomous Vehicle Technology	Continuous rectangular Pallet rack	Multiple	Multi aisle	---	Random Storage	---	First come first serve	Stay idle after storage / retrieval
10	Riccardo Manzini et.al.	Simulation	Effect of system parameterization	Unit load	---	---	---	---	Class Based Storage	---	---	---
11	Russell D. Meller et.al.	Application of Design to Industry	New Aisle Design	Unit load	Continuous rectangular Pallet rack	Multiple	Multi aisle	Single	Random Storage	---	---	Return to start point
12	S.G. Koh et.al.	Analytical	Travel time analysis	Unit load with Tower Crane	Continuous Pick face	Single	---	---	Random and Turnover based storage	Single and Dual Command Cycle	---	---
13	Tone Lerher et.al.	Analytical with computer simulation	Travel time analysis	Unit load	Continuous rectangular Pallet rack	Single	Multi aisle	Single	Random Storage	Single and Dual Command Cycle	First come first serve	---
14	Xuan-Thuong Tran et.al.	Computation al Analysis of Algorithms	Sequencing Problem	Unit load	Open rack	Single	Single aisle	---	Random Storage	Single and Dual Command Cycle	First come first serve	---
15	Yaghoub Khojasteh Ghamari et.al.	Analytical	Order Picking rules to minimize travel time	End of Aisle System	---	Multiple	Multi aisle	Multiple	Random Storage	---	---	Stay idle after storage /retrieval

Continued…

Sr. No.	Author	Study Approach	Performance measure	Type of AS/RS	System Configuration				Control Policy			
					Type of Storage Rack	Number of S/R machines	Number of Aisles	Number of Input - Output Locations	Storage Allocation	Command Cycle	Batching And Sequencing of Orders	Dwell Point Policy
16	Ya-Hong Hu et.al.	Analytical with computer simulation	Travel time analysis	Unit load with split-platform S/R machine	Continuous rectangular Pallet rack	Single	Single aisle	---	Random Storage	Single command cycle	First come first serve	Stay idle after storage /retrieval
17	Yavuz A. Bozer et.al.	Analytical	Travel time analysis	Unit load	Continuous rectangular Pallet rack	Single	Single aisle	One and two	Random Storage	Single and Dual command cycle	---	Stay idle after storage /retrieval
18	Zaki Sari et.al	Analytical and Simulation	Travel time analysis	Unit load	Flow Rack	Multiple	---	---	---	Single and Dual Command Cycle	---	Return to Midpoint

Table1: Overview of research papers Enlisting Decisions Making in Physical Design, Control Policies& Performance Measurement

S. G. Koh et.al.[14] adopted Tower crane which can travel radially clockwise and anticlockwise direction over racks to pick and deposit load at I/O station.

Yaghoub Khojasteh Ghamari et.al.[17] proposed algorithm for order picking in end -of - aisle system to minimize travel run as retrieval request has more number of items to carry from various location. Mohammadreza Vasili et.al.[9] studied characteristic of Mini-Load AS/RS. Heuristic algorithms are used for load shuffling and travel time analysis for storage platform which can be simulated and resulted into reduction in average travel run.

Continuous rectangular racks with random storage allocations are preferred as each cell has equal probability of getting selected. Guiliang Zhou et.al.[4] have used class based storage where heavy loads are stored at lower rows and light loads on upper rows to improve efficiency of loading and unloading. Riccardo Manzini et.al. [12] simulated design of class based storage where A, B, C are three classes are arranged where Class A has more demand than B and C.

Travel time models are derived by various authors under various control policies and dwell point locations. Yavuz Bozer et.al.[19]have derived mathematical expression of travel time model for unit load, continuous rack, Stay dwell policy. Model is then modified for the various positions of I/O station such as I/O station at same location, at opposite end of aisle and at the elevated locations. M. Aslam et.al.[5] implemented travel time model by Yavuz Bozer for designed AS/RS and validated with Matlab simulation

Ya-Hong Hu et.al. [18] derived and validated travel time model for split platform AS/RS which can carry extremely heavy load such as cargo containers for Stay idle dwell point policy. Mohammadreza Vasili et.al.[7] compared mathematical model of Travel time Analysis of split platform AS/RS under stay idle, return to I/O station, return to middle dwell point locations which outperforms for a stay dwell policy over other. M. R. Vasili et.al.[8] have developed continuous travel time model for new AS/RS configuration where two I/O stations are used per aisle which enhances performance of system. For above system vertical platforms returns to I/O station and horizontal platform returns to middle location of row after completion of operation.

Zaki Sari et.al.[20] have worked on travel time mathematical expressions for Flow rack system based on continuous approach. In Flow rack system, load to be stored is travelled over sloping bin and then stored in the rack and retrieval takes place by means of machine. Results are then evaluated for throughput of system to set standards and compared with exact models based on discrete approach. Amine Hakim Guezzen et.al.[1] modeled continuous and discrete mathematical travel time expression for Mobile rack AS/RS. Mobile rack system allows saving in storage area allowing all the racks to unit and form aisle between any two racks by separating them. Tone Lerher et.al[15] proposed travel time model for multi aisle AS/RS with single S/R machine which can travel along multiple aisle. Layout of storage space and efficiency of S/R machine are studied to verify efficiency of analytical and simulation model.

Banu Y. Ekren et.al.[2] developed mathematical multiple regression model for rack configuration of autonomous vehicle storage and retrieval system. Regression analysis has carried out to find out relation between average cycle time and input variables as number of rows, aisles and bays. Xuan-Thuong Tran et.al.[16] studied sequencing problem through local search algorithms where local search algorithm formulates optimal combination of storage and retrieval requests and exact method to get optimal route to perform group of request. N. Jawahar et.al.[10] applied genetic and simple heuristic algorithm approach for performance improvement through storage allocation for minimum movement. Russell D. Meller et.al.[13] worked on different aisle design for space reduction, increased throughput. Proposed design consist of Flying 'V' design, Fishbone design, Chevron Aisle design and this designs are implemented and optimized to get higher throughput and reduction in cost.

The present literature study is going to be utilized for design of new unit load automated storage and retrieval system for library. In library environment, sorting, shelving and retrieval of specific book is laborious and monotonous task which can be simplified by means of developing AS/RS. Proposed system is going to allow storage, retrieval of books along with data cataloguing, acquisition, database record keeping with better storage area management. It makes information management more easy and reliable with increased speed, flexibility and accuracy. It prevents loss of resources under any calamity or disastrous events.

6. Conclusion

From literature study, most of the work has been carried out in area of unit load AS/RS. It includes physical design and various control policies. Performance and throughput of the system is evaluated under various system configuration, dwell point location, sequencing orders, etc. which is presented in table. Newly developed techniques and algorithms such as genetic, heuristic algorithms, exact models are developed and validated through computer simulation with the help of softwares such as Matlab, Arena, FLEXSIM, Microsoft excel, etc. Best possible combination of control policies and system configuration is viable through such computer simulation techniques which make implementation of system cost effective. Still further research is necessary simplify storage assignment policies, batching and sequencing of requests for multi aisle, multi shuttle systems.

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