Study Of ASRS Robotic System Using Vertical Channels

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***Abstract*— The automated storage and retrieval systems (ASRS) are major material handling support systems that are commonly used in the automated factories, distribution centers, warehousing, and non-manufacturing environments. These robot-based handling systems are increasingly applied in distribution centers and are of high demand in e-commerce operations because of their less space requirement, higher operational flexibility and continuous ability to work thereby continuously produce output 24/7. The study will be focused on the advantages and applications of this robotic system in the Automated Storage & Retrieval System, thereby comparing it with the robot operating on the ground.**

Keywords— *ASRS, robotic handling system, e-commerce operations, vertical and horizontal tracks*

I. INTRODUCTION

The automated storage and retrieval systems (ASRS) are material handling support systems that are commonly used in the factories, distribution centres, warehousing, and non-manufacturing environments where automation is implemented. These robot-based handling systems are increasingly applied in distribution centres and are of high demand in e-commerce operations because of their less space requirement, higher operational flexibility and continuous ability to work thereby continuously produce output 24/7. The aim is to study this specific type of Robot based Automated Storage and Retrieval System developed by a company named "**Squid Warehouse Robots"** which uses vertical and horizontal tracks all along the inventory racks, thereby allowing the bot to traverse and reach up to any specific location on the rack and therefore providing certain advantages over other alternative methodologies. This system also requires development of a bot which is equipped with corresponding technology so as to fulfil the operational needs of climbing along the vertical and horizontal tracks installed on the inventory racks.

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II. LITERATURE REVIEW

HISTORY OF ASRS:

Storage has a long history, stretching back to the early days of civilization and the wild berries that were picked at the time, as well as the beast that lay, and after the meal was no longer needed, people would store the surplus. However, the evolution of the proper word "warehousing" has been long and winding. "Automated warehouse" is strongly linked to the rapid development of logistics and its research and development as a higher stage of warehousing. From its conception to present, the automated warehouse has gone through about five stages: manual storage, mechanical storage, automated storage, integrated storage, and intelligent storage.

Fig: In the 1950s, there was a three-dimensional warehouse in the United States that used a bridge-type stacking crane

Fig: The end of the 1960s, the driver operation of the roadway stacker crane warehouse:

The United States was first to employ computer control technology in elevated warehouses, establishing the first computer-controlled three-dimensional warehouse in 1963. Since then, the automated warehouse has grown in popularity in the EU's established industrialized countries, forming a distinct discipline.

In the mid-1960s, Japan began building automated warehouse.

The automation, standardizing, and informationization of product logistics, as well as the creation of centralized distribution centers for urban commodities, have been strongly pursued by developed countries since the 1970s. In a series of steps, they all built large-scale automated three-dimensional warehouses. Automated three-dimensional warehouses grew fast throughout the world in the 1980s, and are now employed in practically every industry.

The first bridge crane was developed by China's Ministry of Machinery in 1963, and the first computer-controlled automated three-dimensional warehouse was produced by China's Ministry of Machinery in 1980. Automation pallet trucks, shelves, and other items have advanced swiftly in our country in the twenty-first century. Large-scale state-owned companies, such as tobacco and pharmaceuticals, were the first to employ automated warehouses. Following 2010, the automated warehouse has permeated all aspects of life in our country, particularly during the Development period, creating a high demand for logistics and distribution centres, prompting a number of e-commerce companies to establish their own logistics and distribution centers, ranging from automated warehouses to formal intelligence.

The current state of the ASRS domain is highly advanced compared to a few decades ago. The first ASRS based system was developed in 1962 and was installed in a book club warehouse located in Guttersloh Germany, and was strictly manually controlled for performing its operations. The advancements in the domains every decade have been very drastic and the level of sophistication, for even the relatively smaller operation has increased significantly, let alone the highly complex and layered operations.

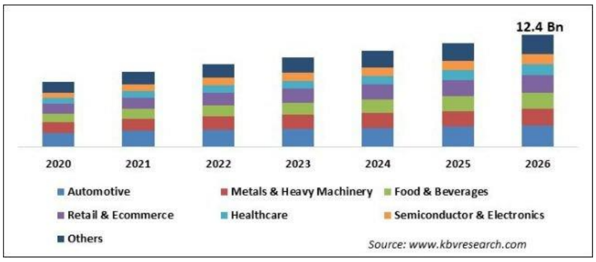

Fig: ASRS market size size projections by end-user. Img Courtesy of KVB Research

After reviewing multiple papers in the domain of Automated Storage & Retrieval Systems ranging from various time has enabled us to get an idea of the current state of the technology and its potential scopes for growth in the coming years. The various types and sub types of ASRS technologies developed until now are further discussed in the following segment.

PRIMARY ADVANTAGES ASSOCIATED WITH ASRS

I] High Density Storage

Space constraints affect a vast number of manufacturing and storage enterprises. These facilities are developed and built to meet immediate needs as well as some predicted future growth. However, when businesses grow and expand, their storage requirements frequently outstrip their current capacity. Continuing to extend horizontally by adding square footage to the building through construction in these instances can be expensive and, in some cases, impossible. When it comes to boosting storage capacity vertically, ASRSs are the most effective approach. To put it another way, ASRSs have the maximum volumetric efficiency, or storage capacity to square footage ratio. As a result, high-density warehouses are a common term used to describe them.

II] Better Safety Operations

Manipulation of a forklift is one of the most dangerous occupations in an industrial setting. Each year, about 100 forklift-related fatalities and 20,000 severe injury cases occur in the United States.

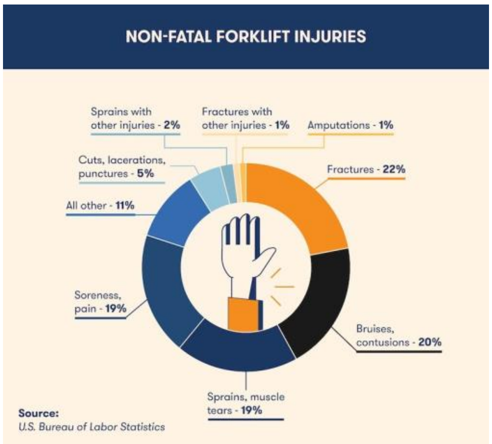

Fig: Most common non-fatal accidents involving forklifts. Img courtesy Big Rentz

III] Increased accuracy and efficiency

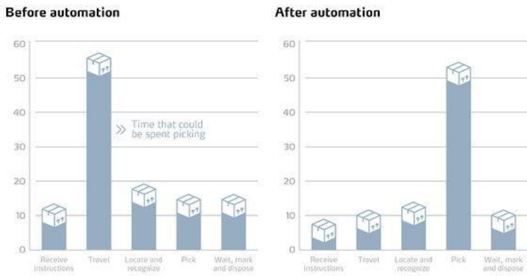

Fig: Efficiency improvements comparison. Img Courtesy: Kardex-Ramster.com

ASRSs, like any other automated system, are configured to do precise repeated duties. When products are handled using an ASRS, they are much less likely to be damaged by human error than when they are handled with a forklift or other means. Aside from labour savings, reducing product waste is a cost-cutting factor that is sometimes neglected when deciding whether or not to install an ASRS.

Another significant advantage of an ASRS is the greater accuracy with which product data is handled. Almost every ASRS operated by a warehouse control system (WCS) or warehouse management system (WMS) can automatically send product tracking data[6].

PRIMARY DIS-ADVANTAGES ASSOCIATED WITH ASRS

I] Initial Investment: The construction of an ASRS is a vast and complicated undertaking. Furthermore, unique materials and reinforcements are frequently required for the structure to resist the loads to be stored. As a result, some businesses that may greatly benefit from ASRSs are unable to use them today. Naturally, the corporations who build these warehouses have conducted extensive research to verify the investment's financial sustainability.

II] Inflexible Tasks:

Despite the fact that ASRSs are modular and expandable, they are often designed to fulfil a single task. Inside the ASRS, the automation is stiff. Stacker cranes, for example, can only move in a specific direction along each axis. Furthermore, the dimensions of the storage site cannot be changed. Within an ASRS, there can certainly be storage places of varied sizes, but they are selected during the design phase.

Changing the structure once it has been erected would be prohibitively expensive. This may have a detrimental impact on a company that, for example, released a new product that exceeds one or more of the storage locations' restrictions. This is why, while deciding whether or not to install an ASRS, future forecasts of production volume and product lines must be factored in[6].

Robotized Warehouse Systems use the concept of shuttle based compact storage system. It requires installation of frames and tracks for the shuttle bot to travel on all over the warehouse. Racks and automated handling equipment, like as cranes or automated vehicles, make up such a system. Aisle-captive (usually cranes) or aisle-roaming handling solutions are available. A crane lifts up a load, generally from a conveyor, and stores it in the 30-40m high racks to execute a storage activity. Driving and lifting in the aisle happen at the same time. For a retrieval operation, the procedure sequence is reversed. It's also possible to run a dual command cycle, which combines a storage and retrieval activity. Loads can also be stored double-deep in the racks using AS/R systems. Cranes with double-deep telescopic forks can be fitted to this end. AS/R systems with Deep Lane, or compact, multi-deep (3D) storage lanes, can store loads even deeper in storage lanes. SBS/RS is becoming increasingly common since the combination of the two subsystems provides great flexibility, cheap operating costs, and enormous storage capacity, but it also creates the managerial issue of how to coordinate the shuttle and the lift. There are three reasons for putting idle shuttles in the first-tier. For starters, because retrieval activities are more vital in an e-commerce warehouse than storage tasks, their dwell policy makes retravel operations easier from the start. Secondly, while dealing with a sequence of outgoing jobs, it minimizes the overall number of shuttles moves. Finally, when all shuttles are at the bottom, inspection and maintenance work may be considerably easier. A shuttle can access any tier with the help of the lift. The lift and shuttles can both operate at the same time. Due of the uniformity of aisles, this paper examines the performance characteristics of the entire system by focusing on just one.[1]

REINFORCED LEARNING:

A clever technique called “Reinforcement learning” is used to improve the performance of an existing system in this study. Changing the configuration of an established system is often challenging because it is a costly and time-consuming process. As a result, the scheduling control should be tweaked to optimize the system's performance. Because the rack of an SBS/RS has different columns and tiers, the make span of storing a load at a certain storage site in the rack is specific to that place. Reinforcement learning is one of three basic machine learning paradigms, with supervised learning and unsupervised learning being the other two. Reinforcement learning is currently widely employed in a variety of domains, including image recognition, data processing, and decision making.[3]

MULTI-SHUTTLE SYSTEMS

Over the last few years, twin- and triple-shuttle S/R machines have been created to increase AS/RSS throughput. They discovered that a twin- or triple-shuttle system running on quadruple-command or sextuple-command has a better throughput capacity than a single-shuttle system running on dual-command. Furthermore, the performance of the twin and triple-shuttle systems can be greatly improved by employing an improved technique of storing and retrieving at the same location, if possible, which they call modified quadruple-command (MQC) and modified sextuple-command (MSC).

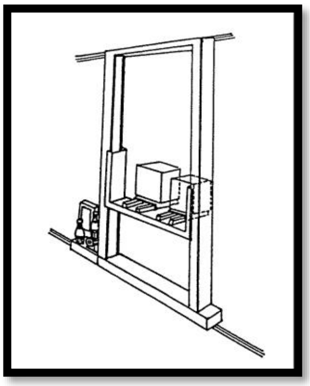

Fig: A twin Shuttle S/R Machine

Another unique concept proposed for reducing the total time consumed in inventory by using a combination of vertical and horizontal platforms. However, the overall cost of installation and maintenance is very high. Stacker cranes are used to access (store or retrieve loads into/from) storage cells in traditional automated storage and retrieval systems (AS/RS). The stacker cranes may move in both vertical and horizontal directions at the same time. Stacker cranes, on the other hand, are insufficient for extremely big loads such as sea container freight since coupled motions often necessitate heavy machinery. This study described a novel type of storage/retrieval (S/R) mechanism for such applications, which was designed with input from AS/RS vendors. To serve N levels of an AS/RS rack, the novel S/R mechanism features one vertical platform and N horizontal platforms, unlike stacker cranes. The vertical platform connects the AS/RS rack's several tiers vertically, whilst the horizontal platforms access the storage cells on a specific tier.

There were certain advantages associated with this new type of S/R retrieval mechanism which are as follows:

- The new AS/RS can carry bigger loads at a faster rate because of the separation of vertical and horizontal movement systems.
- The SP-AS/RS can manage several loads at once since each tier has its own horizontal platform and all HPs and VPs can function independently and concurrently. This, of course, can lead to improved performance.
- Separating vertical and horizontal movement simplifies the mechanism of the device. As a result of the new AS/RS, maintenance is simplified and downtime is decreased.

• Changing rack configurations to suit varied performance needs from practice, such as changing the placement or number of VPs and I/O stations, will be a breeze with the new design.

• The S/R machine could be the single point of failure in traditional AS/RS. In the SP-AS/RS, however, if an HP goes out of order, just the cells in that tier are affected. As a result, the new design has a higher fault tolerance.[12]

OPTIMAL DESIGN FOR RACK DESIGN FOR SB-S/RS

Under the class-based storage policy, an optimal rack design for shuttle-based storage and retrieval system (SBS/RS) have been developed. A typical design of an SBS/RS is illustrated in Figure 13 where each tier and aisle have a shuttle and a lift. Shuttles are used as storage/retrieval devices in the system to store/retrieve loads to/from storage locations. For cargo that are typically transported by small containers, lifts offer vertical mobility (i.e., totes). Because each aisle only has one lift, it is frequently the system's bottleneck. As a result, an alternate SBS/RS design with a two-lift table lift mechanism has been created. The two lifting tables attached on both sides of the lifting system increase the capacity of the lifts in this. arrangement. The authors consider an SBS/RS with two lifting tables on the left and right sides of the lifting mechanism in this study. Shuttles are tier captives whose primary mission is to store and retrieve totes from storage facilities. Each bay may contain one tote, and racks (on either side of an aisle) are made up of bays. Because the number of tiers and bays in each aisle of the SBS/RS examined is the same, they imitate a single aisle. The lifts are positioned at the end of aisles and can individually transport two totes. Based on the dual command (DC) scheduling rule, Transaction seizes the available lift. There is an I/O point on each aisle.[5]

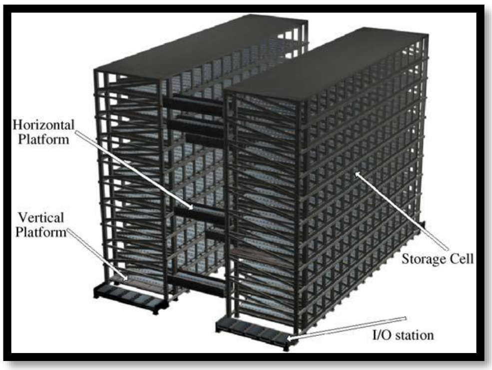

Fig: The new S/R mechanism of AS/RS

[III] CASE STUDY: SQUID WAREHOUSE ROBOTS (BY BIONIC HIVE)

The Concept: Squid is an autonomous robotic fleet developed by Israeli startup BionicHIVE for structured packing and storage in warehouses. The robot can select anything from the ground up and adapt it onto any existing warehouse infrastructure. According to the company, the robot adapts to any warehouse's working environment by utilising existing facilities, packages, and storage racks.

Nature of Disruption: Squid is a synchronous autonomous robotic fleet with three-dimensional movement capabilities that can perform a variety of tasks. BionicHIVE's ML-based algorithmic engine can learn issues caused in one warehouse and apply resolutions to all warehouses within the network thanks to its embedded control system with real-time data analysis. It may be installed immediately on any standard pallet rack in any warehouse to automate all package handling from receipt to shipment. Squid has floor-to-ceiling picking capabilities, which means it can select the packet from any spot, whether it's on the floor or 20m/60ft up. BionicHIVE says that its service-based model may help warehouses lower operating costs while also meeting the growing demand for higher stock-keeping unit amounts and dynamic pick face selecting.

Fig: Squid Bot

Outlook: Existing autonomous mobile robot warehouse automation solutions are unable to address the fundamental warehouse inefficiency problem. Furthermore, because these solutions necessitate dedicated space, considerable implementation effort, and significant financial expenditures, they cannot be executed at scale by warehouses. Squid, according to BionicHIVE, is the first robotic fleet that can retrofit automation on existing warehouse infrastructure with minimal change and downtime, allowing existing operations to continue while offering automation as a service.

Squid is fully autonomous with 3-dimensional movement and can learn problems using smart real-time data analysis. Movement on the ground is possible through image processing of QR codes to identify pathways and avoid obstacles. The unique guided rails help them to climb vertically and move horizontally to locate the products. The specially designed robotic arms with suction cups make it easy to handle the products from the pallet box to the rack and vice versa. This system complies with the universal safety standards to ensure the safety of human-robot collaboration (HRC). Also, the Squid robots are capable of learning seamlessly and improvise performance using Machine Learning.

These bots climb the racks using the vertical channels installed on the racks and therefore can reach any location on the racks, thereby providing excellent inventory assortment methodology while reducing the efforts taken by a human(employee) for the same process.

For implementing the Squid robots in a warehouse, the racks present in the warehouse need to be modified. The racks in which the inventory is stored, are modified by installing vertical and horizontal channels along every rack. Also, at the bottom of the rack is installed a curvy inclination for the bot to climb into the vertical channels. These channels help the bot to grip its one pair of wheels which is used for climbing purpose while the other remains inactive in this process and are basically driven(wheels) when the bot is moving from one point to another on the ground.

Fig: Squid Bot Working

The electronics of the bot include a custom built highly advanced on-board computer, wireless communication module, 3 pairs of motors for locomotion(1 pair for the drive,1 for the turning on ground and one for keeping the bot upright while climbing the racks), sensors for object detection and mapping, load sensors, small sized robotic limb with suction cup end effector, power backup, camera sensor for adjusting itself wrt the curved inclination for climbing vertically along the racks as well for product code scanning purposes.

[IV]RESULTS AND DISCUSSIONS

The study of the various Automated Storage/Retrieval System has been successfully conducted and it is clearly derived that the advantages of Robotic ASRS are numerous, some of which mainly include better accuracy and operational efficiency, better storage density, savings in space, labor costs, 24/7 availability, savings on other operational costs, safety etc.

Monitoring and manipulating the scheduling as well as the software-end storage parameters of any ASRS plays a vital role in improving the performance efficiency of the system in totality.

Case study of the SQUID bot by BionicHive is conducted. The vertical and horizontal rack-based system utilizes a 3-Dimensional Shuttle based SRS and enables pick up and drop of inventory from and to very precise desired coordinates within the storage space throughout the warehouse facility.

[V]CONCLUSION

Implementation of robots with vertical and horizontal movement capabilities in the ASRS domain like the tier-to-tier SBS/RS along with reinforced learning, multi-shuttle based ASRS methodologies, etc. provide direct advantages in enhancing the operational efficiency and optimizing operational time of conducting the whole process. However, it’s quite obvious that each and every type of ASRS requires unique types of infrastructure and management procedure, those being some of the trade-off parameters to be considered before finalizing any of these systems for installation in a warehouse facility. Also, different warehouses have different infrastructural capabilities and therefore the approach for solving the inventory management process varies accordingly.

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