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Steve Tomko and Helge Hornis, Ph.D, Pepperl+Fuchs

Automated Storage and Retrieval Systems (ASRS) are at the heart of any fully automated warehousing system. As in all automated solutions, users demand nearly perfect, (i.e., 100%) availability and exceptionally fast operation at the lowest possible price point. While the raw speed of an ASRS along each axis of motion is limited by the selected drives' components, modern sensor technology – the eyes of the ASRS – allows designers to coordinate positioning motion, increasing the effective speed of the ASAR. This type of motion has been common for the coarse motion. Coarse motion can be controlled by a number of different solutions from string potentiometers, encoders, long-range sensors with absolute position output, and more recently, precision linear encoders. Fine positioning, i.e., the precision position correction not possible by these previously mentioned technologies, has typically been done one axis at a time. Since fine positioning is done at low speeds, the time penalty is particularly large and, therefore, offers significant room for improvement.

Reliability of the storage and retrieval process can also be enhanced using better sensing technology. It is intuitively clear that storing a pallet of goods at a storage location requires a different tool motion than retrieving the same pallet at a later stage. This is especially true when the loads are high, resulting in appreciable deflection of the retrieval tool (e.g., the forks.) When an ASRS approaches an empty storage location, the forks are typically raised by a substantial amount thus making sure the insertion process is smooth. Next, the pallet is lowered and the forks are retracted. When retrieving the pallet the forks are inserted in the low position and then raised until the pallet is completely supported. For the smoothest and fastest operation it is desirable to use a sensor system that can securely detect the two insertion positions independent of load and height above ground. Such a solution automatically compensates for product variances (weight) and storage bin location.

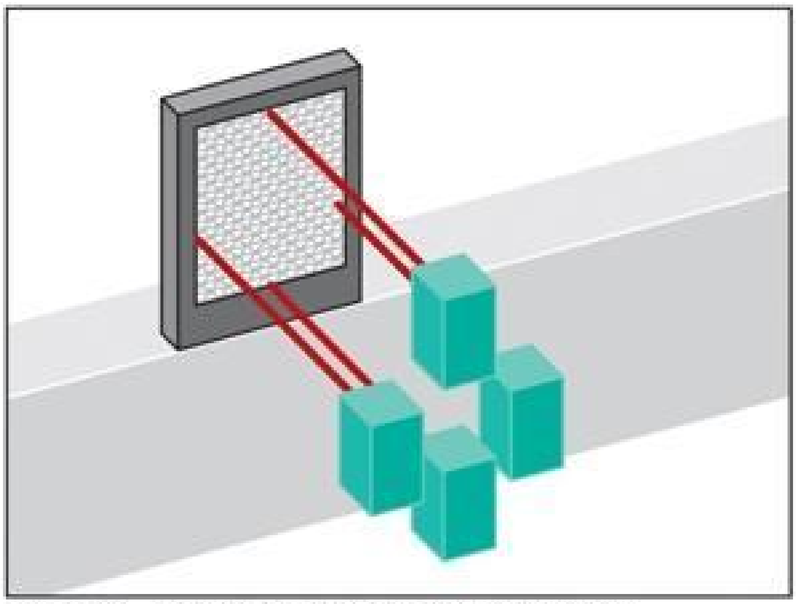

Figure 1. A conventionally constructed fine rack positioning system using four sensors and a reflector. The ASRS has reached its final position if all sensors see the reflector (i.e., the sensor outputs are HIGH). If the ASRS is too far right, the right most sensor is OFF indicating that a correction to the left is needed. Coordinated moves are not possible since the relative offset is unknown; only the final good position can be detected with certainty.

In the past, tool positioning was accomplished by using standard sensors in combination with targets attached to the individual storage bin locations. A common way of detecting the ASRS position is based on using four photoelectric sensors, mounted in a square pattern on the ASRS. Each of the storage locations is equipped with a square reflective metal plate that is just small enough to fit within the beam pattern created by the photoelectric sensors. Besides being time consuming during the build phase, sensor alignment can be a problem, and coordinating xy motion is not possible. Figure 1 shows such a setup after the tool location has been placed in its final position. The alignment has been selected such that the outputs of all four sensors in ON in this case. It is quite obvious that the precise placement of the target is not only critical but time consuming. Sensor alignment is another possible problem.

Fortunately, a new solution utilizing vision technology addresses those negative aspects and makes ASRS more reliable and faster. The prefabricated support structures used to build large storage bin systems typically comes with prestamped holes that eliminate the need for drilling. After the frame is bolted together, there are usually several unused holes. The vision-based system takes advantage of these holes, using them as visual markers for alignment and target position, **without the need for reflective metal plates or additional peripheral devices.** The labor savings are significant. With no holes to drill and no peripheral equipment to buy, mount, and adjust, manufacturers can build and deliver their system faster and more economically

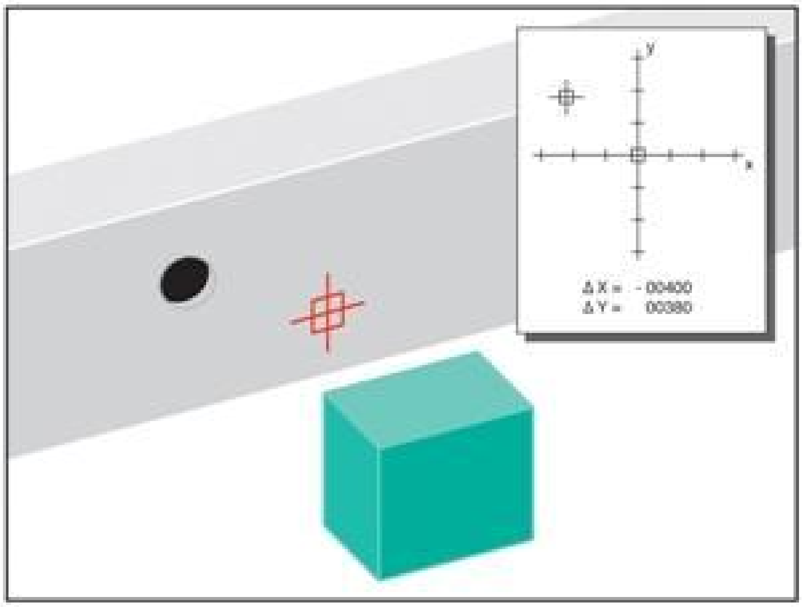

Figure 2. A vision-based solution utilizes a feature (in this case the hole that is part of the beam material) to calculate a relative offset. These numbers allow the ASRS controller to directly and precisely correct the motion and quickly position the ASRS where necessary. Using the existing hole makes this solution less costly and more reliable, while increasing the speed of the system.

Instead of mounting a collection of photoelectric sensors on the ASRS, a single vision-based sensor is attached. array.

In addition to addressing cost and speed concerns of modern ASRS solutions, a vision-based approach has the added benefit of increasing troubleshooting functionality. For instance, a well-designed product has the ability to store and transmit error images. These can be uploaded for analysis supporting maintenance personal in their tasks to determine fault causes and possible solutions. Error images speed up problem resolution in cases where no valid target hole has been detected. This helps in quickly identifying issues like covered target holes or a grossly misaligned sensor.

Utilizing the full functionality of vision-based ASRS alignment sensors for fine positioning has the ability to both reduce the cost of the installation and increase the speed to the storage and retrieval process by means of creating position-dependent coordinated moves. But even in situations where this is not possible (retrofit systems come to mind) a vision-based system is desirable. This is another example where utilizing the power of vision technology solves difficult applications with ease.