Pallet Detection Systems Help Automated Forklifts Modernize Warehouse Operations

The right 3D sensing system can help automated forklift trucks (AFT) achieve better than 98.5% pick accuracy and reduce mission time while simplifying even the toughest high-rack operations.

WHITE PAPER

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In the spring of 2018, for the first time ever, the U.S. Bureau of Labor Statistics (BLS) reported that there were more job openings than job seekers.

While U.S. manufacturing is the poster child for the labor gap — the National Association of Manufacturers (NAM) predicts that more than half of the 4.6 million manufacturing jobs created during the next decade will go unfilled — logistics, warehousing, and distribution are feeling the pinch too, victims of their own success and escalating e-commerce business trends. The pressure on warehouse operators isn't likely to go away anytime soon. Market research company Technavio predicts that warehousing services will continue to grow at an average of 6% per year through 2021 due to growing demand from manufacturing, pharmaceutical, and health-care sectors. One way companies will fill the labor gap, Technavio says, is through the adoption of technology, such as machine-readable bar codes and robots, to "increase speed and reduce errors in the order fulfillment process." Automation offers a way forward for warehousing and logistics companies despite a lack of trained, certified workers, such as forklift operators.

Today, many logistics companies are leaving business on the table due to a lack of workers, but that isn't the only financial pressure. In addition to lost potential revenue, warehouse operating margins are being squeezed by the need to pay overtime to keep operations going. In the past, only a few warehouse and manufacturing organizations had the financial wherewithal to automate forklift operations. Why the high capital costs? The technical challenges of fielding automated forklift trucks (AFTs) for the safe pick and rack of palletized goods are not trivial, and the infrastructure investment is sizable. Today, however, lost revenues and higher labor costs are changing the return-on-investment (ROI) calculation for the better, helping warehouse operators financially justify new ways of automating their operations. At the same time, new low-cost sensing systems, such as 3D machine vision, are helping reduce infrastructure requirements while improving the accuracy, speed, and safe operation of AFTs in messy real-world warehouse environments.

Messy Warehouses? No Problem

Warehouses are messy environments in many ways (and literally on many levels).

A truck arrives and the forklift swarm ensues. Human operators move pallets to temporary staging areas to free up trucks and open the dock for the next delivery. At the same time, other forklifts move pallets from staging areas to predetermined rack locations so they can be located easily for the next distribution stage.

The need for speed combined with the vagaries of human material handling means that pallets may be turned at a slight angle from the norm (yaw) or placed perpendicular to the aisle, leaving no clear approach to insert forks into the pallet pockets. Both of these conditions challenge the completely autonomous forklift, which follows preprogrammed paths, magnetic tape, and rack reflectors from staging area to pallet rack. Giving the AFT a way to "see" the rack, through pallet detection technology (machine vision or computer vision) can significantly reduce the pushed racks

A	P	Q
Availability	Performance rate	Quality rate
↓	↓	↓
Total hours planned - lost time	Actual machine speed	Number of good products
Total hours planned	Design machine speed	Total products made
%	%	%

and damaged goods that can trap an AFT in an aisle for hours. Machine vision increases overall equipment
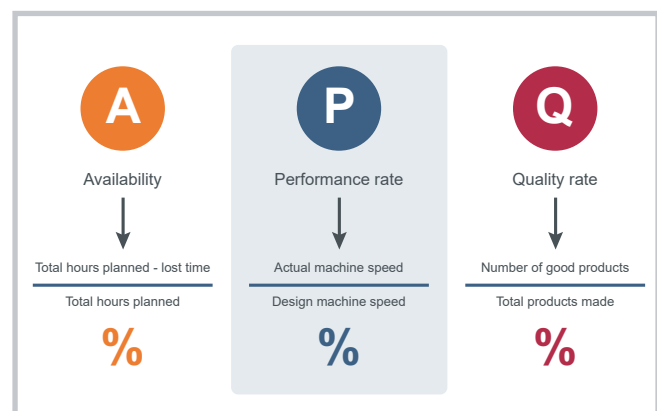
efficiency (OEE), which is the gold standard for measuring manufacturing productivity and is based on the equipment's availability, performance rate, and quality rate.

Of these three factors, AFT OEE is primarily based on the performance rate metric, which decreases as a robot experiences slow cycles and small stops. By reducing pallet location and pick times from five seconds to under one second, with significantly better accuracy and repeatability than standard AFT systems, AFTs that can sense their surroundings offer considerably better OEE metrics and therefore faster paybacks.

## i**fm's PDS solves the beginning and end of every AFT mission**

Today, best-in-class pallet detection systems allow AFT to "see" its surroundings, and they provide the vehicle with all the data necessary to make good decisions while picking and dropping pallets.

ifm's PDS is mounted between the forks of the AFT. After receiving a material handling mission, the vehicle triggers ifm's PDS camera to collect a 3D image of the pallet or rack. An embedded computer inside the camera, running a custom algorithm developed by ifm, filters the image for optimal AFT guidance and determines the mission target's position relative to the AFT with 6 degrees of freedom (6DoF).

At the mission's terminus, ifm's PDS conducts a volume sweep, using a similar process to locating the pallet, to verify that the rack or staging area is ready to receive the pallet.

Today, only ifm's PDS AFT guidance system determines a pallet's position — loaded or unloaded — with 6DoF and fully scans the 3D volume of the receiving rack or staging area before completing the mission. This focus on both ends of every mission allows ifm's customers to achieve new levels of OEE productivity and reduce cycle times.
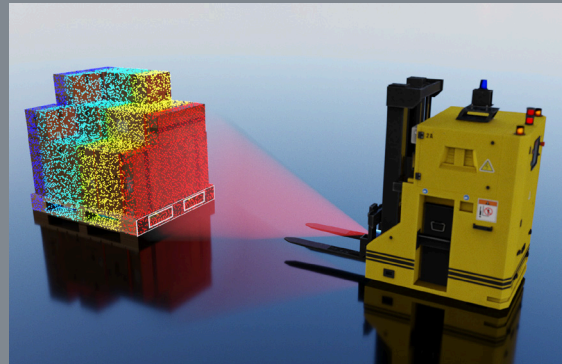
Pallet Detection System Insights

AFT customers have multiple sensing options for pick-and-rack operations, with each technology offering different pros and cons.

Commercially available automated pallet detection systems (PDSs) use a variety of remote sensing technologies. Cutting-edge, solid-state, embedded time-of-flight (ToF) solutions offer the speed of stereoscopic systems without the higher cost and additional computer requirements while providing full 3D sensing capability across an entire field of view. And unlike lidar scanning systems, which provide only a 3D cross section of a rack or pallet and pose aiming challenges on high lifts, a PDS can sense the complete shape of a stacked 3D pallet or rack. Useful data from lidar systems is further reduced by computational algorithms

that filter out reflectors and other outlier data points caused by highly reflective materials, such as plastic shrink-wrap, resulting in less data for robust AFT guidance and potentially reducing OEE metrics.

ToF camera-based PDSs offer other benefits, such as the power of the illumination system, which can penetrate shiny materials such as plastic shrink-wrap better than lasers can. The invisible infrared radiation used by PDS systems also makes them impervious to ambient light, another problem for traditional machine vision AFT sensing systems.

Software That Keeps Getting Smarter

The final piece of the PDS puzzle lies in software that adds intelligence to the AFT's sensory system. But for do-it-yourself solutions, PDS software is the job that is never complete. For example, developing and optimizing PDS detection algorithms takes real-world warehouse test suite environments with hundreds of different pallet types, conditions, and configurations. After starting with standard pallets, ifm engineers realized that a truly robust solution needed to be able to respond to hundreds if not thousands of outliers and special conditions. So ifm engineers moved their development from the lab to a warehouse test suite, quickly ramping up their pallet training library from a handful of samples to more than 300 pallets. From there, the test suite has grown to more than 1,000 pallet types, conditions, and variations.

PDS software needs to be able to quickly locate any pallet pocket, whether on a GMA or CHEP pallet, a US CHEP or an Australian CHEP pallet, or a damaged pallet or skid. And because pallets and pallet mixes are always changing, the software needs to be tunable to adapt to changing pallet dimensions and to differentiate pallet structures from other configurations. For example, a PDS needs to be able to differentiate between two pockets on a single pallet of unique dimensions and the appearance of a unique pallet created by the pockets of neighboring pallets. Such situations can quickly overwhelm a homegrown AFT sensing solution. So ifm works with partners in real-world warehouse scenarios to improve the robustness of PDS warehouse intelligence.


Single Pallet Pull

Double Pallet Pull

Pallet Partners

To develop a robust PDS algorithm capable of improving OEE without interrupting existing operations, ifm worked with several large distribution enterprises, refining their PDS algorithms as the test suite increased from 300 to 500, 700, and well beyond 1,000 pallets, pallet types, and pallet conditions. And ifm continues to add to that test suite.

The years required and millions of picks necessary to develop a robust PDS solution lead many customers to realize that what they seek isn't a technology or a solution but a partner in automated warehouse optimization.

Tackling the PDS solution from all sides and perspectives not only helps develop robust algorithms but also adds to overall system efficiency and reduces cost of ownership. ifm designed an algorithm to run directly on the O3D3O3 camera at the heart of its PDS. This highly integrated, embedded solution runs faster than competing solutions because all processing is done on board the AFT, reducing the robot's need to communicate with remote servers and guidance systems. Highly optimized, embedded solutions run faster than PC host and AFT controller-based solutions, improving OEE metrics while reducing maintenance requirements, since embedded hardware and operating systems are supported longer than consumer-grade solutions.
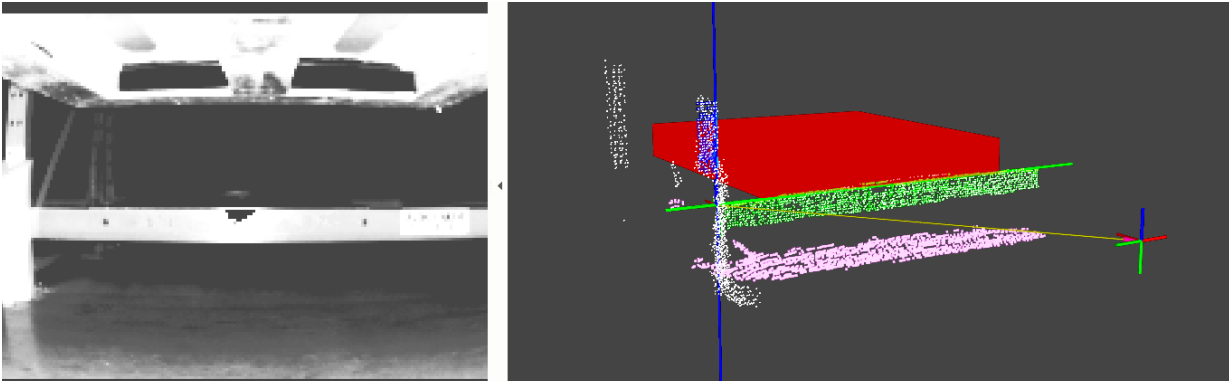
Rack detection (Left: amplitude image from camera, Right: point cloud showing the position of the rack)
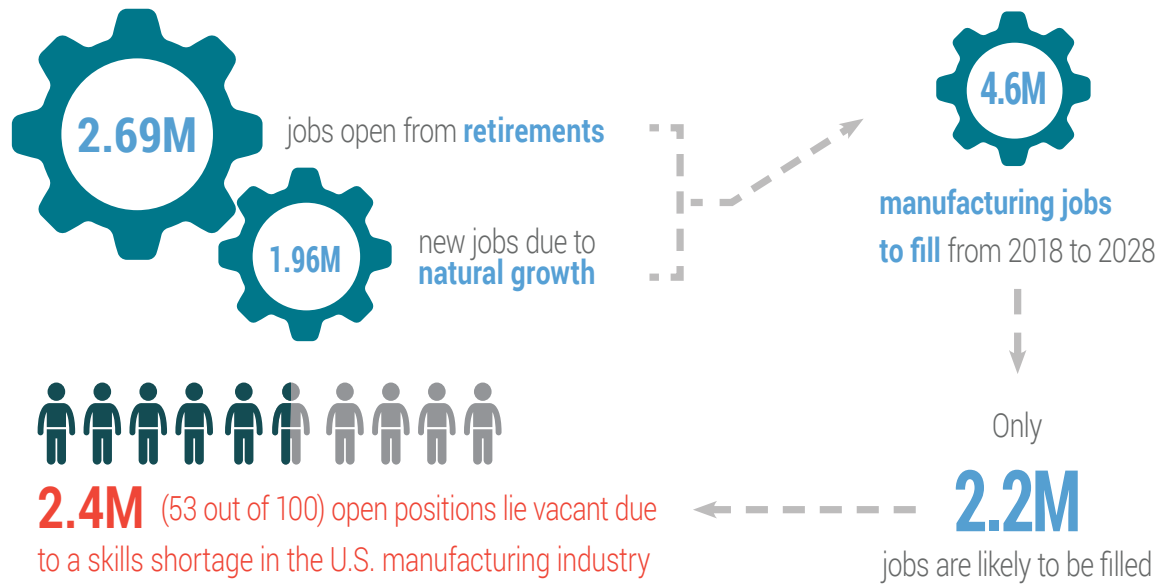
All clear? PDS software tackles both ends of the AFT challenge

Few AFT systems on the market today offer pallet detection algorithms robust enough to handle both picking the pallet and verifying that the rack location is empty before racking.

Most PDS sensing solutions don't try to scan empty rack volumes because of "noise" caused by the ubiquitous reflectors used on racking systems and warehouse floors. These reflectors cause excessive "blooms," or bright spots, in standard camera-based pallet detection systems.

ifm's PDS software uses intelligent filters to remove outliers and blooms in the sensor's field of view caused by reflectors, shrink-wrap, and other reflective surfaces. This allows the PDS to safety determine whether a rack volume — not just a programmed rack location — is ready for a pallet. AFTs that use ifm's PDS with both GetPallet detection and GetRack volume scanning handle both ends of the mission without incident.

The skills gap may leave an estimated 2.4 million positions unfilled between 2018 and 2028

2.69M jobs open from **retirements**

1.96M new jobs due to **natural growth**

4.6M **manufacturing jobs to fill** from 2018 to 2028

Only

2.4M (53 out of 100) open positions lie vacant due to a skills shortage in the U.S. manufacturing industry

2.2M jobs are likely to be filled

Source: 2018 Skills Gap and Future of Work Study, Deloitte and the Manufacturing Institute

For these reasons and many others, ifm customers prefer an "expert tuning" algorithm development process and support versus a "black box" machine learning algorithm approach. By leveraging ifm's technology and operational expertise, customers can successfully handle the conditions unique to their warehouses, such as issues related to loaded versus unloaded pallets, overall load reflectivity, or using GetRack to guarantee that a space is clear before loading a pallet to a storage rack or other location.

PDS software needs to easily integrate with any AFT controller and warehouse management system. ifm specifically chose standard programming languages, such as C++ and Python, and open source robotics and machine vision programs that allow clients to access and grow their systems without having to learn proprietary languages. ifm has even wrapped the standard TCP/IP-based industrial communication protocol at the heart of its PDS with a CANopen software wrapper, helping the PDS work in any number of vehicles, from forklifts to automobiles to autonomous vehicles. In fact, ifm purchased the ToF sensor company PMD to guarantee that its hardware is tightly integrated with the most user-friendly software programming environments. ifm's expertise in industrial applications means ease of use today, this year, and for many years to come.

Fifty years of experience fielding warehouse, robot, and machine vision solutions, along with experience gained by multiple active deployments of PDS-powered AFTs, allows ifm to bring together different technologies to reliably and ruggedly solve the unique application challenges of AFTs.

AFT success requires more than technology

While autonomous forklift sensing systems and control software have come a long way in solving common problems encountered by PDSs, even in high-mix operations, autonomous navigation isn't easy or cheap. The biggest cost associated with AFTs — beyond the cost of developing an effective solution — is infrastructure: the wireless communications, magnetic tape or other navigation systems, reflectors, and real-time processing required to monitor fleets of autonomous vehicles moving in a shared warehouse space. But for large operations, running three shifts of 10 forklift operators or more, automating the process can save more than $1 million in direct labor alone, resulting in payback in three years or less. Reduced recruitment and shrinkage overhead make the return even more attractive.

Finding the right sensing option for the last meters of the pick-and-rack operation can make the difference between nearly 100 missions per shift (12 missions per hour over eight hours) and no missions per shift. If the pallet detection system cannot verify the rack volume as well as the pallet condition and location, productivity will inevitably suffer.

For all these reasons, choosing an AFT PDS requires more than familiarity with 3D sensing systems and mobile robots. It takes a partner that understands the challenges of the modern warehouse environment, from the shortage of certified operators to the floor layouts, navigation systems, and reliability requirements of industrial warehouse systems. Developing a successful PDS requires thousands of man-hours of testing solutions in real-world warehousing environments all around the globe and in all kinds of operational conditions.
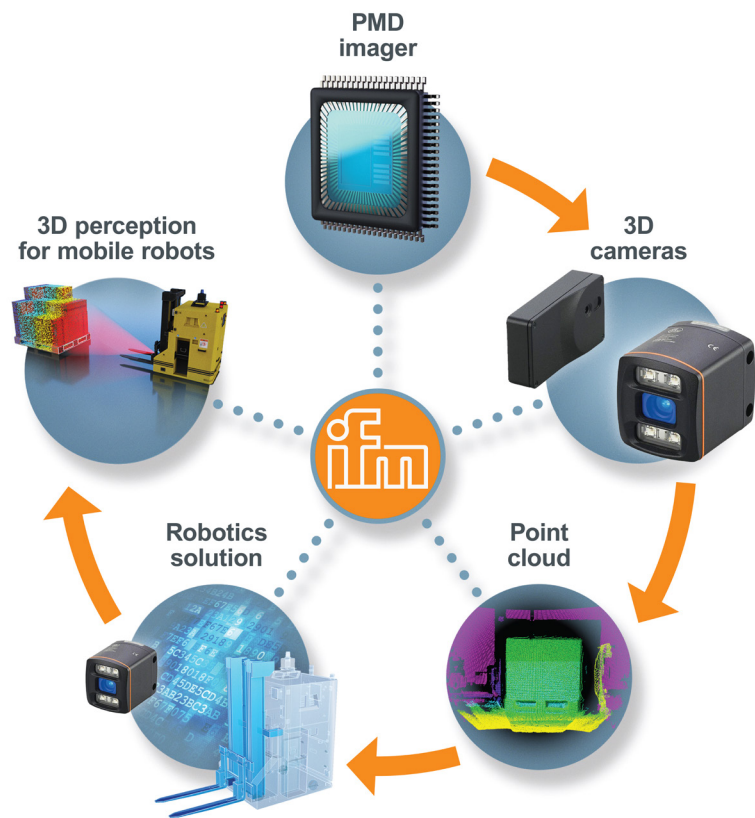
ifm's unique position in the industrial electronics, machine vision, robotics, and warehouse industries for more than 50 years give its engineers a 360-degree understanding of the challenges facing warehouse and plant managers struggling to squeeze more productivity from their material handling systems. With attention to both picking and racking, ifm's solid-state PDS solutions deliver just the right amount of functionality at the right price and with the ruggedness and reliability that warehouse operations require.

For more information, visit ifm.com/us/robotics or contact Garrett Place at +1 484-343-5676