EMBEDTEK

SensorForks: Material Handling Vision System

The Internet of Things is making its way to industrial trucks, and it brings the potential to digitally transform safety and productivity. EmbedTek recently worked with Cascade Corporation, a lift truck attachment manufacturer, to develop SensorForks. SensorForks are lift truck forks with a wireless industrial-hardened camera system. They give operators a real time, close up view from the tips of the forks that they've never had before.

"Adding technology to a mature product is the way of the future," said Greg Nagle, Global Product Manager for Cascade Corporation. "Material handling, like most trucking, is becoming more automated, and adding camera systems with the ability to identify the tilt and angle position of front-end attachments is key."

EmbedTek brought its extensive experience in real-time wireless connectivity, camera technology and vast camera knowledge to the table for this challenge. The engineering teams used their intellectual property (IP) from existing camera systems, software, and display processors as building blocks to implement vision technology in a new way.

Visibility of Load

Imagine you are a forklift driver at a busy Home Depot. You are tasked with pulling a pallet of tile off the top of an aisle rack during store hours. You section off the aisle, engage your lift to the third shelf, move the fork forward, and feel it make contact. But you can't see what it made contact with. If the fork protruded through to the next pallet, it could push it off into the other aisle. If the fork is caught on the edge of a pallet, hundreds of pounds of inventory could topple in your direction instead.

Fork truck incidents have been identified as the leading cause of accidents, property damage and deaths within the warehouse industry.

Now, imagine you are a forklift operator in a modern warehouse. Instead of Home Depot racks three levels high, you are pulling and placing pallets on racks eight levels high – some 50 feet in the air – and you are trying to line the forks within 1 to 2 inches of a load you cannot see. You can only rely on locational awareness to know if your fork and the payload are in alignment. This has always been an issue, according to Nagle.

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Accidents have happened when a pallet has been pulled off incorrectly and it takes the whole racking system down. Just one dropped pallet can cost a company expensive product inventory or require hazardous cleanup – warehouses move thousands of pallets and metal baskets a day.

Cascade set out to develop SensorForks as a driver enhancement tool similar to the back-up camera on a car. Providing forklift drivers with a close up view from the front edge of the fork and the payload could contribute to fewer dropped loads, fewer damaged goods, and increased efficiency.

Camera systems on forklifts are in their infancy because of a few major design hurdles. Wired systems may not hold up long-term due to the constant raising and lowering of a 50-foot mast. And wireless systems would not only need to survive the rough industrial environments, but require delivering the video stream in real-time through a solid steel truck.

"We needed to find a partner that was bold enough to make a wireless solution possible," Nagle said.

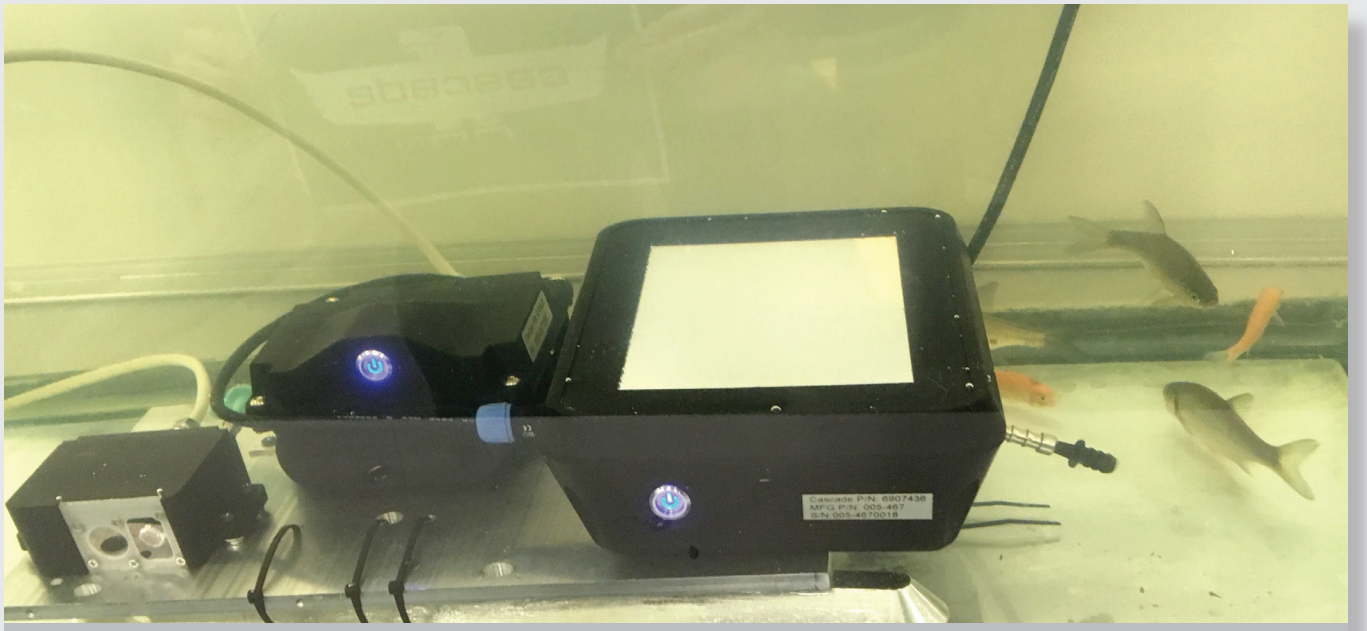
The EmbedTek team first leveraged their own library of knowledge – successful products which they had developed for other vision, wireless, and processing applications as well as leveraging commercial-off-the-shelf (COTS) components. Utilizing these known building blocks helped the team get a faster start on a more innovative solution.

Environmental Protection

When considering the camera requirements, the team quickly realized the necessary technology was not available off the shelf so it was apparent that they would need to develop a custom solution.

"Part of the challenge of designing camera systems is to thoroughly understand which sensor(s) is right for a particular application," said Kent Tabor, President and Chief Technology Officer of EmbedTek. "In an effort to get to market as quickly as possible we try to utilize COTS components where possible. In this case we had to design our own camera and system because available components were too large, couldn't handle the shock/environment and introduced too much latency (or video lag). SensorForks required a highly engineered enclosure unique to this application that no COTS components could accommodate. "

For starters, the camera housing in the tip of the fork is about the size of a thumb. The sensor needed to be a high performance camera that would work well in low ambient light and provide good depth of field in the video. It also had to be durable enough to handle the extreme G-forces that results as forklifts bounce along concrete floors, the abrupt impact resulting from contacting racks and walls, as well as operate in rain or standing puddles.



SensorForks camera system submerged in water to test against the IP67 standard for water ingress.

EmbedTek engineers took lessons learned from designing other custom cameras developed for in-vehicle image capture applications, toll booths, image-guided surgery, and sewer inspection applications to develop an original camera design. The camera has a tilt sensor to determine the angle of the fork, uses a laser time-of-flight sensor and ultrasonic sensor to determine the distance from the fork of forward object(s), and includes a tip sensor to verify when the fork is inside the intended pallet while short of the pallet behind the targeted pallet.

Custom memory allocation, communications, sensors, optics, filters, lenses – all were created to fit within the small recessed envelope in the tip of the Cascade fork. The final product incorporated all of this in a custom, sealed enclosure following IP67 standards for protection against dust and water ingress.

For power and communication, EmbedTek designed what we call the "backpack." The backpack mounts on the back of the fork at the truck carriage. It connects to the camera assembly via an Ethernet wire which runs inside the fork itself. The backpack contains an ARM processor, a radio frequency (RF) transmitter, and a rechargeable battery that lasts more than 12 hours. The backpack also is durable enough to handle shock and vibration and also meets the IP67 standard.

"The backpack serves as a wireless bridge between the fork and the display mounted in the cab," said Tabor. "There were many details to consider but having the video reach the operator screen without visible lag, dropped frames and with accurate tilt and distance measurement were the most important."

Zero Latency

Once the team perfected the performance of the camera, the information needed to be delivered to the driver in the cab as close to real-time as possible. Even a half-second delay would deliver incorrect information to the driver.

SensorForks' communication between the camera and the cab display is a wireless, RF connection. Without careful consideration and proper design for this environment, RF signals would not be reliable and would experience problems due to crosstalk interference, resulting in poor video quality. In a forklift application like this, it is even more challenging because the RF signals have difficulty going through or around the solid steel structure of the forklift mast and cab. This issue can cause flickers in the display as the signal drops and the connection restores. In addition to interference, video latency can also occur in software while processing the image and displaying it.

"To accomplish near zero latency and uninterrupted camera video to the operator is very difficult to do and is hard to find in the market," said Tabor. "Our communication link in SensorForks is best-in-class."

For this application, it would not be acceptable for the display to buffer seconds of video time while controlling a pallet that is 50 feet in the air. This would result in the operator thinking they are farther away than they actually are. Imagine if you were backing up your car and your rearview camera showed you that you were 4 feet away from the car behind you when in reality, you were only 4 inches away. The consequences of this type of buffering would be devastating.

EmbedTek needed to develop a solution that provided reliable video streaming without flicker or choppiness, and no buffering – in real-time as detectable to the human eye, which is about 20 milliseconds.

The team designed two pieces of software to achieve this. The backpack software runs on a Linux OS to process video data from the camera as well as a gyroscope from the tilt sensor and distance sensor. It also reports the status of battery power. The other program is the graphical user interface (GUI) that runs on a touchscreen display with a powerful Intel® Processor in the cab. A stable video stream ensures no lag time.

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Planning Ahead

The collaboration between Cascade and EmbedTek led to a commercially viable product with optimized performance and scalable packaging built for the environment around it. The initial release of Cascade SensorForks is considered Phase 1. EmbedTek and Cascade are already working on additional functionality, such as systems integration and using light detection and ranging (LIDAR) technology to gauge distance.

"Consumers have access to technology in their everyday products, and will expect to see the same features in the equipment they use on a jobsite," Nagle said. "Data streams that connect equipment and handling to every aspect of the warehouse are being used to optimize systems and plan maintenance. It is important for our equipment to tie into telematics systems going forward."

EmbedTek designs, invents, and manufactures computers, software, sensors, cameras, and displays for original equipment manufacturers. Our systems improve the quality of imaging in healthcare, simulation programs in the military, video analytics in security, and much more. Throw any challenge at us, from demanding environment and ergonomic requirements to High Level Assembly and nonstandard I/O. We'll evaluate it, carefully attack it, and solve it.