

Whitepaper | Multi-camera system for industrial trucks and off-highway vehicles

How Bosch is improving accident prevention and working conditions in the off-highway market

Invented for life



Forklifts and other industrial trucks present a high risk of accidents. The camera-based assistance system from Bosch for forklifts mitigates particularly accident-prone situations by improving the view around the entire vehicle. Thanks to this, people and other objects in the forklift's surroundings are better protected and the driver's stress level is reduced.

Introduction

Industrial trucks have become essential work equipment in logistics and warehousing. This is especially true in the case of forklifts, the most widespread application. They lift heavy loads, transport them from A to B in production facilities, warehouses, and production lines, and maneuver effortlessly through the narrowest aisles of shelving. This also makes them indispensable helpers for fast and efficient logistics in online retail, which has been experiencing a boom in the last several years due to changing consumer behavior.

While the advantages of using forklifts are obvious, the dangers in everyday work are often underestimated. According to data from the German Social Accident Insurance (DGUV), more than 13,500 accidents resulting in personal injury involving forklift trucks were reported in 2020 alone ^[1]. In a quarter of forklift accidents, the person injured was the driver, and in 47 percent of cases, the accident victim was hit, crushed, or run over by a forklift. These figures exclude countless accidents resulting in material damage that are unnecessarily time-consuming and incur significant costs.

Therefore, the drivers must constantly have the entire area around the vehicle as well as the load on the fork in view while driving and maneuvering ^[2]. According to interviews with drivers, this causes anxiety and puts them under constant stress, which significantly impairs their performance and often leads to driving errors. The necessity of surveying the entire environment at places with restricted visibility and ensuring the stability of the load often leads drivers to maneuver slowly, reducing the productivity of forklift operation.

In addition to the mental stress, physical strains also occur. These can be caused, for example, by a tense sitting position or constantly turning their heads left and right while driving backwards to maintain a good view of the driving path. This can lead to chronic health problems for the drivers and considerable downtime for employers. This is therefore particularly problematic since, due to language barriers or the required training, it is not easy to find suitable drivers.

In addition to the health consequences, accidents cause increased documentation, clarification, resolution, and subsequent training effort within the company. To increase occupational health and safety when operating forklifts, signalers are required in many companies to help the forklift drivers maneuver during loading and unloading. In practice, however, they are often not immediately available, especially during peak periods of activity, which causes annoying wait times and associated costs and further increases the stress level. To reduce these wait times, drivers often drive

without signalers despite a limited view, which leads to a higher risk of accidents.

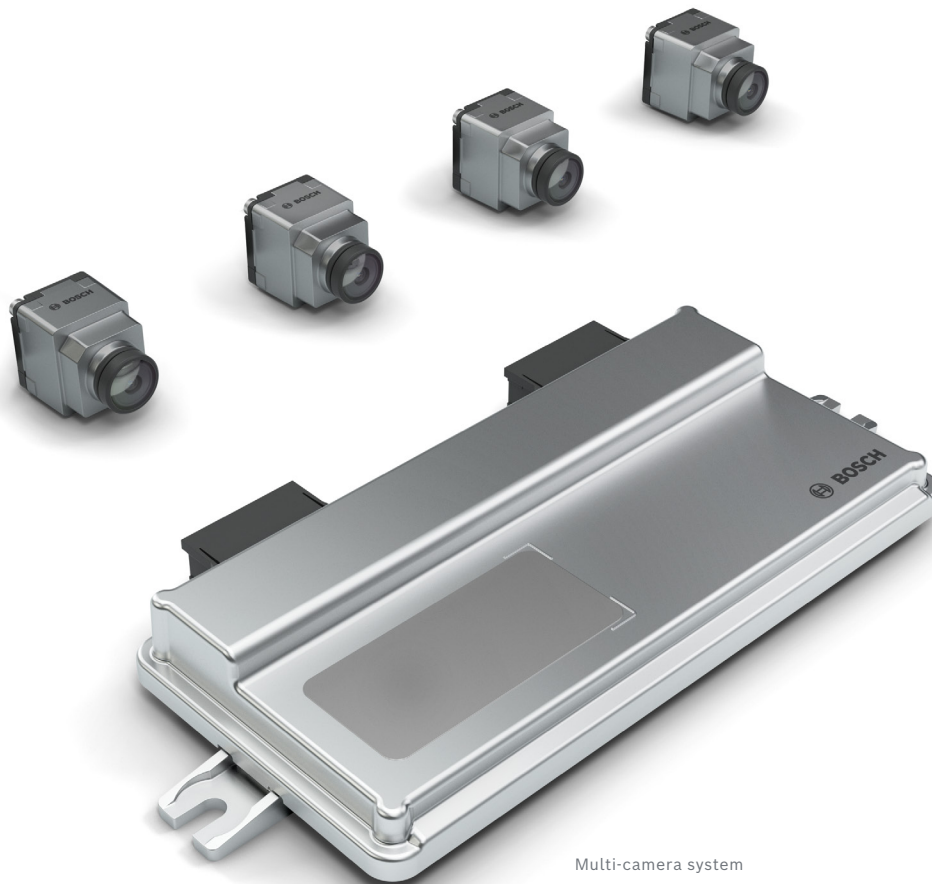
As demonstrated by Bosch's experience in other industrial fields, such as the commercial vehicle sector, electronic assistance systems can make an important contribution to improving the level of safety and reducing the health-related strains for drivers, thereby maintaining or even increasing productivity in the long term. To do this, however, the functions must be purposefully conceived and designed to ease the users' burdens and support them in a useful way, rather than making them feel like they are being replaced while doing their jobs. This means, for example, that its operation should be simple and intuitive.

Industry-wide collaboration

In order to understand all the requirements of an assistance system for industrial trucks – and in this case especially for forklifts, which have the largest market volume of all applications – and be able to develop appropriate assistance solutions, Bosch performed a detailed analysis of potential problem situations. Various associations, representatives of employers' liability insurance associations, and companies in the fields of production, construction material, beverage sales, retail, and rental, as well as service companies, among others, were involved.

In this way, it was determined, for example, through workshops, events with drivers, observation days at companies, and individual interviews, which work situations involving forklifts are particularly problematic. Across all industries, the participants named driving backwards with the forklift as number one. They criticized in particular poor visibility and ergonomics. In second place they mentioned driving slowly with a load on the fork and frequent changes of direction, such as when maneuvering. In both situations, the driver must constantly look in many different directions, which distracts from driving and increases the risk of an accident. This also aligns with surveys conducted by the DGUV institution, according to which 55 percent of accidents occur while driving backwards and 98 percent occur at slow speed. In these cases, 90 percent of the people injured were standing too close to the forklift, meaning that the necessary safety clearance from the vehicle was not maintained.

From the results of the requirements analysis and supplementary DGUV surveys on accident outcomes, their frequency, and their severity, three common particularly accident-prone situations (use cases) can be identified in the operation of forklifts. First is starting from a stop or driving in the often narrow aisles and paths, where there is a danger of a collision with



Multi-camera system

people or other objects; second, people or vehicles crossing between rows of shelves in intersections with poor visibility are overlooked; and third, accidents occur while maneuvering during loading and unloading, for instance when pallets with goods are loaded onto shelves or trucks.

Given this information, an assistance system must effectively support forklift drivers during their work: it must improve the general view around the entire vehicle – especially the view of the vehicle’s path while driving backwards and in blind spots when the driver’s view is blocked by the load on the fork – in order to mitigate the three aforementioned situations in particular.

Multi-camera system

In a benchmark comparison of various sensor concepts performed by Bosch, the optical sensor system with cameras emerged as particularly suitable for the requirements of forklifts. Image display and processing features can be implemented and interpreted by the user much better with a camera-based system than with other sensor systems. The assistance system from Bosch comprises four compact near-range cameras and an electronic control unit that creates a 360° representation of the vehicle’s current surroundings and displays it to the driver on the monitor in the cockpit. Depending on the current working situation, the driver can switch between different views on the

monitor. The various screen views (e.g., the individual views of the various cameras, 360° all-around view, full screen, or split screen) can be configured by the driver. In addition, the system switches to the appropriate view automatically based on the movement of the vehicle without the driver having to make the effort to set this in the operating menu.

The possible viewing modes are:

- ▶ 3D top view (“bird’s-eye view”): the system uses the camera data to create a top-down view of the vehicle, which gives the driver an impression of the vehicle’s surroundings on every side. If the vehicle moves, the on-screen image of the vehicle’s surroundings changes accordingly. The top-down view is spatially represented by a projection, which in practice leads to a realistic representation of raised objects such as people, shelves, and goods. The top view zoom (manual and dependent on the vehicle’s speed) offers an automatic focus for precise maneuvering of the vehicle in narrow spaces.
- ▶ Panorama view: in this mode, the viewing range of the front or rear camera is opened to 180°, which is especially helpful while driving backwards out of overhead doors, since the camera’s beam angle is greater than the driver’s visual range and the camera tilts out of the overhead door before the driver’s head.

As a feature, the driver can allow the vehicle's predicted trajectory to be displayed on the screen with distance indicators as maneuvering and positioning aids. This feature supports the driver while driving and maneuvering, but also when a new forklift operator takes over. In this case, the new driver often does not know the previously set angle of the steering wheel, which can cause the vehicle to abruptly change direction when it begins to move. Accidents often happen when the forklift touches a person standing directly in the vicinity of the vehicle, for instance, to discuss the transport task with the forklift driver, or when the forklift steers directly toward a row of shelves.

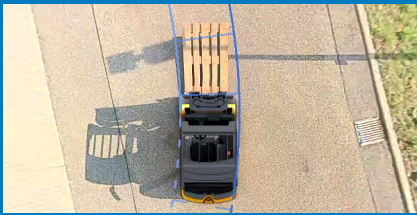
In addition, the system offers a virtual camera panning function. In the case of the front view, for example, the camera image digitally turns with the steering angle to better capture the visual range relevant to the driver.

To generate the different views, Bosch uses a high-performance graphics processor. This delivers a high-quality image and a high degree of detail, especially in the areas where the images overlap during stitching (merging the individual camera perspectives to form an overall view). This means that the operator does not overlook any objects shown on the monitor during forklift operation, and objects in the transition area between two camera ranges are not shown twice.

Sight Assist

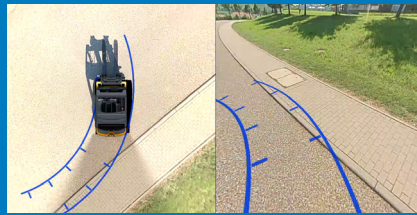
Depending on the working situation, the driver can switch between different views on the monitor

360° surround view



3D top view (static bowl)

Maneuver- and positioning aid



Dynamic trajectory based on steering angle with distance indicators in selectable colours

Panorama view



Panorama view sees more than the driver can

Automatic top view zoom



Automatic zoom function to simplify low-speed manoeuvring in narrow environment

Panning



Digital panning of camera depending on the steering angle allows the driver to see more of the relevant area

Dynamic stitching



Switching of stitching lines depending on driving direction and camera field of view



Automotive ethernet interface



Diagnostic and calibration tool

Fast and easy system calibration by customer for different vehicle variants possible

Multi-camera system as a retrofit solution

Experience shows that industrial trucks such as forklifts have a long service life. For this reason, Bosch has developed a special retrofit solution so that existing vehicles can also benefit from the added safety provided by the multi-camera system. The complete package comprises four compact near-range cameras (including control unit), a universal wiring harness, a 10-inch touch display, and a set of camera mounts. It thus includes everything needed for quick and simple installation. When developing the system, particular emphasis was placed on delivering high functional quality in all usage conditions. For example, the exclusive use of digital camera technology ensures high image quality even in adverse light conditions, such as at dusk, in low-light working environments, and in backlight situations. The high-resolution

display ensures very good image representation and readability even in direct sunlight or rapid changes in brightness. A sturdy housing made of powder-coated die-cast aluminum also makes the display suitable for use in harsh outdoor environments, for instance.

All functions of the retrofit solution are controlled by a touch interface on the display, so that no additional keypads need to be integrated into the forklift cockpit. For example, the intuitive menu can be used to switch between different camera views of the system, allowing the driver to choose between front/rear views and the 360° all-around view in full screen or split screen, as well as bird's-eye and panorama views. The panorama view, in particular, offers considerable added safety when maneuvering in areas with poor visibility thanks to the expanded viewing range of 180°.

Bosch Retrofit solution

360° surround view



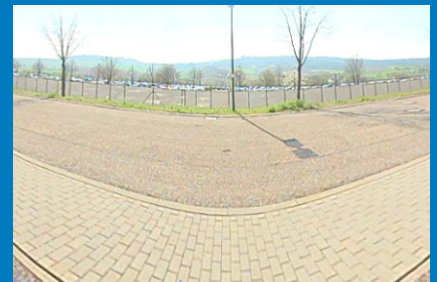
3D top view

360° surround view/rear/front view



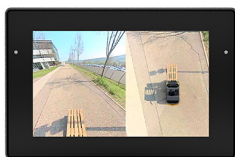
Split-screen

Panorama view

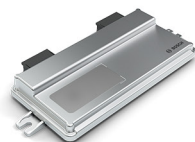


Panorama view sees more than the driver can

Retrofit solution



1x
10-inch touch display



1x
Control unit



4x
Near-range camera



4x
Camera mount



1x
Universal wiring harness



Components overview

Application-specific system development

Bosch designs assistance systems and functions for industrial trucks, but also for other industrial and off-highway applications, such as construction, agricultural, and municipal vehicles, to be precisely tailored to their specific applications. To do so, a modular sensor system with ultrasonic, radar, and camera systems was developed which can be used and combined as needed. In forklifts, multi-camera systems are especially suitable due to the special use profile. They have excellent image display capabilities for viewing on the monitor.

In other industrial trucks, such as aerial work platforms, Bosch uses ultrasonic sensors to protect the work basket when driving in blind spots. Since the beginning of 2022, the new 24 V ultrasonic sensor system for near-field monitoring of the working area has been on the market in two versions. Although both 24 V systems feature identical hardware, there are differences when it comes to the processing of the sensor data and thus the functional scope of the different versions. While the basic system simply measures the distance to a specific obstacle, the high-end solution also features object localization. When it comes to further automation of machinery, ultrasonic systems with safety-relevant functions for surround sensing are becoming increasingly important. Compared to other systems such as laser scanners, modern ultrasonic sensor systems are considerably more affordable with good performance, even under difficult conditions. For the off-highway sector, the first safety version of the Bosch off-highway ultrasonic sensor system with performance level C in accordance with ISO 13849 will be available on the market starting in 2024.

Radar systems have a very large detection range, so distant objects can also be reliably detected and tracked. Their robustness against environmental influences (e.g., rain, snow, dust, and fog) makes them predestined for off-highway applications such as construction machinery or agricultural vehicles.

All assistance systems from Bosch can be easily integrated into the vehicle's electronic system. In the field of industrial trucks, the communication protocol already supports, for example, future electronics interfaces, the standardization of which is being actively pursued by the Association of German Engineers (VDI) and manufacturers ^[3].

Summary and outlook

Forklifts and other industrial trucks present a high risk of accidents. Therefore, the drivers must constantly have the entire area around the vehicle as well as the load on the fork in view while driving and maneuvering. This causes constant stress and can lead to health problems. The multi-camera system from Bosch for forklifts mitigates particularly accident-prone situations by improving the general view around the entire vehicle – especially the view of the vehicle's path while driving backwards and in blind spots when the driver's view is blocked by the load on the fork. To do this, a 360° representation of the current surroundings of the vehicle is generated and displayed to the driver on a monitor. Depending on the current working situation, the driver can switch between different views on the monitor. The system thus offers a perfect all-around view. People and other objects in the forklift's surroundings are better protected and the driver's stress level during operation is reduced. A retrofit solution for quick and simple installation is available for existing vehicles. In addition to the multi-camera system, radar and ultrasonic systems round out the off-highway surround sensors from Bosch.

Sources

- [1] Deutsche Gesetzliche Unfallversicherung [German Social Accident Insurance] (publisher): Statistik Arbeitsunfallgeschehen 2020 [Statistics on the incidence of accidents in the workplace for 2020]. Online: <https://publikationen.dguv.de/widgets/pdf/download/article/4271>, accessed on April 10, 2022
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- [3] VDI-Gesellschaft Produktion und Logistik [Association of German Engineers, Organization for Production and Logistics] (publisher): VDI 4482: Assistenzsysteme für Flurförderzeuge [Assistance systems for industrial trucks]. Online: <https://www.vdi.de/richtlinien/details/vdi-4482-assistenzsysteme-fuer-flurfoerderzeuge>, accessed on April 10, 2022

Further information

www.bosch-mobility-solutions.com

Bosch Engineering GmbH is a wholly owned subsidiary of Robert Bosch GmbH and is head-quartered in Abstatt, Germany. As a systems development partner to the automotive industry since 1999, the company with its more than 2,800 associates offers development services for powertrains, safety and convenience systems, and electrical and electronic systems – from the original concept to series production. Specialized in electronics and software, it draws on Bosch's proven large-scale series production technology to develop tailored solutions for a wide variety of applications in passenger cars, commercial vehicles, off-highway and recreational vehicles, and in rail applications, ships, and industry. Bosch Engineering GmbH also coordinates all the Bosch Group's motorsports activities.



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