White Paper
Towards Improved Forklift Safety

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1 Introduction

There are over 1 million forklifts in operation in the United States with an estimated 2 million operators (6 million including part time operators) [Chugh] and nearly 2 000 automated guided vehicles (AGVs) in use in the US. Forklifts are a necessary piece of material handling equipment for many industries. If used properly, they can reduce employee injuries. Unfortunately, they can also pose some safety risks to drivers, pedestrians, and other equipment and goods. This White Paper summarizes presentations and discussions from the PerMIS 2009 Special Session on "Performance Measurements to Improve Forklift Safety." Papers presented during this special session are listed in the references section.

Attendees of this special session included:

Attendee	Organization
Roger Bostelman,	NIST
Mark Austin	OHSA – Baltimore/Washington Office
Benny Forsman	Danaher Motion/Kollmorgen
Richard Ungerbuehler	SkyTrax, Inc.
Mike Shneier	NIST
Will Shackleford	NIST
David McCartney	US Army Aberdeen Test Center
Luke Fletcher	Massachusetts Institute of Technology
Garrett Place	IFM Efector
Steve Ruth	IFM Efector
Tim Meyers	Toyota Material Handling

This paper is structured to first summarize information from special session papers presenting statistics and issues which define the forklift safety challenge. Following are remedies presented and discussed during the session that can improve forklift safety. Last are discussions and recommendations to further improve forklift safety from the final discussion period of the special session. Some excerpts are copied directly from the papers and presentations from this session.

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2 Forklift Safety Statistics and Issues

- OSHA estimates that there are 110 000 accidents each year.
- $135 000 000 immediate costs are incurred due to forklift accidents
- Each year, an additional 94 750 injuries related to forklift accidents are reported
- Approximately every 3 days, someone in the US is killed in a forklift related accident
- Approximately 31 600 employees suffer some type of injury.
- Losses affect employees through physical and mental suffering.
- Almost 80 % of forklift accidents involve a pedestrian
- 18.8 % of forklift accidents occur when a forklift strikes a pedestrian
- One in six of all workplace fatalities in this country are forklift related
- According to OSHA, approximately 70 % of all accidents reported could have been avoided with proper safety

(some of these statistics are courtesy Bircher America, Inc.)

Forklift operating environments include: pedestrians, blind spots, both indoor and outdoor use, narrow aisles, building columns, 24 hour per day operations, and can include tight turning radii. Pedestrians contribute to accidents since they sometimes don't understand forklift stopping distances and try to "beat" forklifts. Many incidents involve limited driver field of view (FOV) issues where driver controls are mostly designed to drive facing the forks. This forces drivers to see through bars, chains and cables and at times causing their FOV to be completely blocked in the travel direction. Drivers are usually forced to sit facing towards the load, yet look backwards to drive. Researchers report that 75% of side tip-over's occur when a forklift is empty, leading them to conclude that these incidents are due more to speeding than other causes. Losses that affect employers due to forklift accidents include damage to equipment and loss of productivity. Most lost work time reported in 2007 was due to fork truck accidents totaling over 11,040 which is: nearly two times higher than cases involving transportation and material moving, nearly 7 times more than production worker involvement, and over 8 times higher than office or administrative worker incidents.

3 Current Remedies to Improve Forklift Safety

Methods used to reduce forklift accidents include: driver training, safety procedures, equipment maintenance, restricted/designated areas of operation, and facility design. While these strategies will always be elements of workplace safety programs, collision statistics clearly indicate that training, signage, and floor markings for traffic control are not enough to assure a safe environment. Real-time monitoring and control can improve both safety and efficiency.

There are a number of safety systems being researched or in use today. These safety systems are briefly mentioned here and are discussed in more details in [Ungerbeuhler]. Automatic barrier guards can be installed to prevent fork trucks from falling off a vacant receiving dock. These systems prevent forklifts from running off an open dock and can stop a 4500 kg (10 000 lb) forklift traveling at up to 0.8 m/s (4 mph). Warning lights can be installed at blind corners to warn of oncoming forklifts. Safety system designers now have new technologies to consider for hazard control, particularly for detecting collision and speeding hazards. For pedestrian detection, a prototype system employs a simple radio frequency (RF)-tag placed in safety vests worn by warehouse workers. An RF receiver was installed on each truck alerting drivers to the presence of any workers within the detection radius of the receiver. The researchers found this wearable RF tag prototype to be a low cost solution that they recommend be used along with other safety measures. One company places a prototype RF transceiver on each vehicle. A similar battery-powered portable transceiver is clipped onto any pedestrian entering the warehouse. The transceiver creates a virtual protection zone around the vehicle or person. When the zones intersect, the transceivers energize a warning signal for both the pedestrian and the vehicle operator. This approach is a viable solution for workers and pedestrians.

Driven largely by the need for smart surveillance and security systems, image processing technology for detecting, identifying, and tracking people in video images is now used in commercial applications. One pedestrian tracking system analyzes the movement of customers in commercial buildings. Processing images from overhead cameras, the system determines the number of customers entering a store and the exact paths taken by customers shopping in the store. In retail and banking applications, the technology is used to track queues of customers and to signal when more check-out lanes need to be opened. While this technology has not yet been applied to collision-avoidance systems, it can be expected in the near future.

Systems based on presence detection sensors indicate that a vehicle is within the detection distance or zone of the sensor. In most cases, there is some ability to configure or engineer the detection distance. Inductive or capacitive proximity sensors and photoelectric sensors, all of which are familiar to automation engineers, fall into this category. An invisible, infrared light beacon mounted on the top of the vehicle is detected by a receiver up to 25 m away and can trigger warning lights or audible alarms for pedestrians and other drivers. Microwave sensors work similarly and can shape the detection zone to match an area of interest. Some companies offer warehouse intersection warning products using microwave sensors. Four sensors and a warning light are hung above an intersection with microwave sensors aimed in all four directions. A vehicle approaching the intersection is detected and triggers the appropriate warning light.

Further complication exists when both automated guided vehicles (AGVs) and forklifts operate in the same space. One company provides accurate and reliable tracking of forklifts, AGVs and other industrial vehicles inside buildings in real time to an accuracy of 5 cm to 20 cm using onboard vehicle vision to view 2D barcodes mounted to the facility ceiling. Important to many safety applications, indoor position systems determine the instantaneous speed and orientation (heading or direction of travel) of each tracked vehicle.

Several sensors, logistical aspects and tasks are needed to bridge between manned and driverless vehicles as shown in Figure 1.

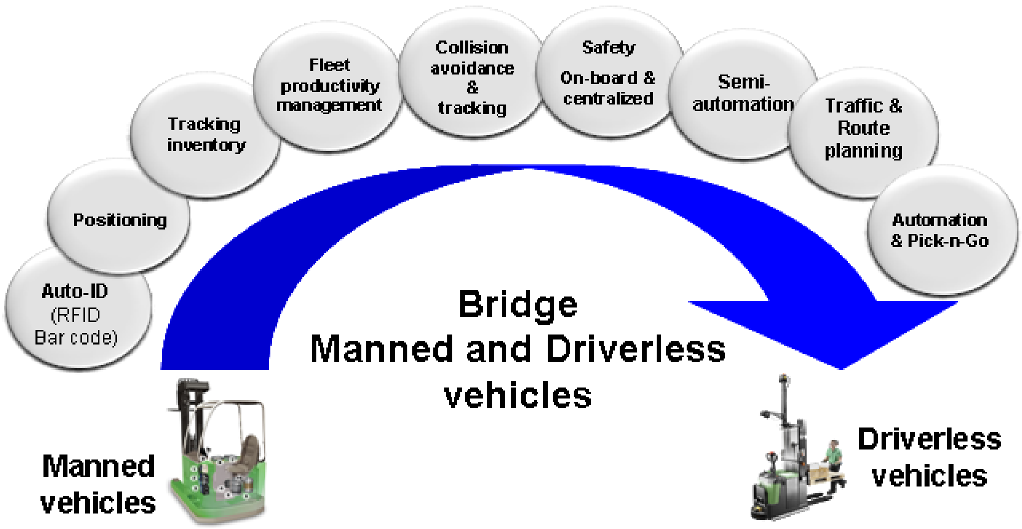

Figure 1 – Drawing showing sensors, logistical aspects and tasks needed to bridge between manned and driverless vehicles

In facilities where autonomous vehicles are used, a different set of safety requirements exists. Autonomous vehicle control systems must assure that inter-vehicular collisions are prevented, and the vehicles must be equipped with safety devices to prevent collisions with people or equipment. The current ANSI/ITSDF B56.5 standard is being improved to include noncontact safety sensors that detect standard-sized objects with specific reflectivity in the path of automated and manned industrial vehicles with automated functions. Two dimensional (2D) laser distance and ranging (LADAR) sensors are currently being used on some forklifts to assist driver field of view and on many AGVs to detect obstacles in the vehicles' paths. 2D LADAR measures range to obstacles along a plane. These sensors work well but are limited by their 2D measurement capabilities. Three dimensional (3D) imaging is needed for viewing overhanging obstacles in the vehicle path. 3D light detection and ranging (LIDAR) sensors are an upcoming sensor technology being studied and proposed for use on both forklifts and AGVs. Stereo vision is now in use on some AGVs to provide 3D viewing.

4 Discussions and Recommendations to Further Improve Forklift Safety

Discussions among the session attendees addressed manned forklifts and AGVs, as well as pedestrians near vehicles, where all three can occupy the same material handling environment. This section provides a summarized transcript of the discussion portion of the session called: "Recommendations Towards Next Generation Forklifts to be Safe" followed by group recommendations. Also listed are two additional recommendations supplied after the group discussion occurred.

<u>Group Discussion</u>

The group discussion was spoken, recorded by a secretary and later summarized without regard to quoting individual participants. It was captured without attribution to encourage expression of opinions. NIST expresses no opinions within the following summarized transcript:

> Every facility is dramatically different, but the same types of safety steps can still be taken. There is worry because of cost that the forklift industry will be forced to install scanners on forklifts. There are things that can be done today for using the intelligence of the onboard forklift controls more than how they're currently being used. These things are not being done today because customers are not asking for them. The reason is because customers want their forklift drivers to be able to quickly operate forklifts without costing users additional money or training. Small progressive steps towards a safe forklift solution are suggested rather than a leap forward solution.
>
> The forklift industry is similar to the automotive industry, where the element not completely being controlled is the people around the vehicle. For

example, how would a driver know where there is a pedestrian in a distribution facility when their view is blocked unless spotters are used? Also, how would the driver know what are pedestrian intentions in a facility? Some sensors to track people are very expensive. Should everyone wear a sensor like an RFID tag? If so, what happens when that person forgets their tag and then whose fault is it if there's an accident? OSHA says it is the forklift driver's fault. This points to the need for additional safety measures, such as removing pedestrians from the forklift environment or adding safety sensors or better driver FOV sensors to the forklift.

Industry comparison of AGVs versus forklifts, when considering their relative industry sizes, points to AGVs as being safer. An AGV may be too expensive to implement in a factory versus a forklift although there is a need point of affordable innovations. There is a need for the ability to track both pedestrians and vehicles. The challenge with the AGV market is the cost and the safety. 2D LADAR scanners are a great product but very costly to implement to view overhanging obstacles and to completely improve the drivers FOV. The issue is cost versus safety.

Some companies are doing crossover from forklifts to AGVs. Others are converting manned industrial trucks to automated vehicles and light trucks. Long term goals are ideal but where is the balance for cost and safety? With the high cost of forklift accidents per year being $135M, there is a need to find a balance. Toyota's focus is on training to help with overcoming the safety issues associated with automated facilities by training everyone from the administrative person to the forklift drivers.

Vehicle tracking systems are effective for forklift safety, although customers are more interested in the cost versus the safety. So, there is a crossover of taking jobs versus a safe, efficient facility where ultimately safe, efficient systems are more cost effective in the long run. Productivity and efficiency are the driving forces. Companies are not trying to lay off people or get rid of forklift drivers but produce more goods. Freight transport and storage are all cost driven. Companies recognize a safety need, but no one wants to pay for it.

For automated forklifts that follow workers down aisles for manual order picking, several commands are introduced into the system so the order picker can command the robot and the robot will remain safe. However, these commands are more for the order picker than the robot.

<u>Recommendations</u>

The following summarizes the recommendations for improvements to increase forklift safety arising from the discussion and presented papers.

1 Follow the OSHA checklist; enforce the requirement that all drivers wear seatbelts.

2 Ergonomics of vehicles are currently difficult so change the driver's seat so that the driver is not required to turn his/her head backwards to see in the direction of travel when the forklift is carrying a load

3 In noisy environments, add rear backup lighting. Currently drivers rely on their hearing to know when a pedestrian is in the way. Therefore, there is a need for something to replace acoustics. A suggestion would be to use a laser beam that projects 15 m in front of the vehicle through the intersections to tell pedestrians where the forklift is intending to go.

4 Adding sensors and cameras to forklifts to improve the driver's FOV are suggested and being tested at NIST. See Figures 2 and 3.

5 Because there are nearly 1 million forklifts in use today in just the US, there needs to be safety equipment that retrofits to existing forklifts, as well as being designed into new forklifts.

6 There is a need for the ability to track both pedestrians and forklifts and provide the information to the driver and/or to the pedestrians.

7 Systems are needed to control forklift speed to prevent tip over. This must be done this without impacting productivity. Technology is needed that can provide advance warning of hazards (earlier reaction time) and can directly limit forklift speed to assure adequate stopping distance based on location, load, vehicle type, and known hazards.

8 Automatic load weight display is needed for the driver, similar to the speedometer in a vehicle, that would continuously show load weight and changes in % of vehicle lifting capacity as the vehicle moves, lifts, etc. *(post session input from*

Ted Jurca, Integrated Visual Data Technology, Inc.)

9 Possible forklift improvements may be *(post session suggestions by Rusty Smith, McCall Handling)*:

- Driver pin-code entry into a keypad or use a card scanner mounted to each forklift to allow that driver to operate the forklift with “black box” (similar to aircraft black boxes) information on who last operated the forklift. Potential uses of this improvement may be to:
  - Recall which operator was running the forklift after an incident occurs,
  - Allow drivers who caused prior incidents to control the forklift at limited speeds and/or carry limited loads.
- Load sensors in the seat to shutdown and ensure a forklift “park” condition when the operator leaves the seat.

Figure 2 shows an experiment performed by NIST using several 3D LIDAR imagers near the edge of a loading dock to detect both positive and negative obstacles. Figure 3 shows a color camera mounted on an extendable boom on a forklift to increase driver field of view of B56.5 standard sized obstacles when blocked by loads, bars, and chains.

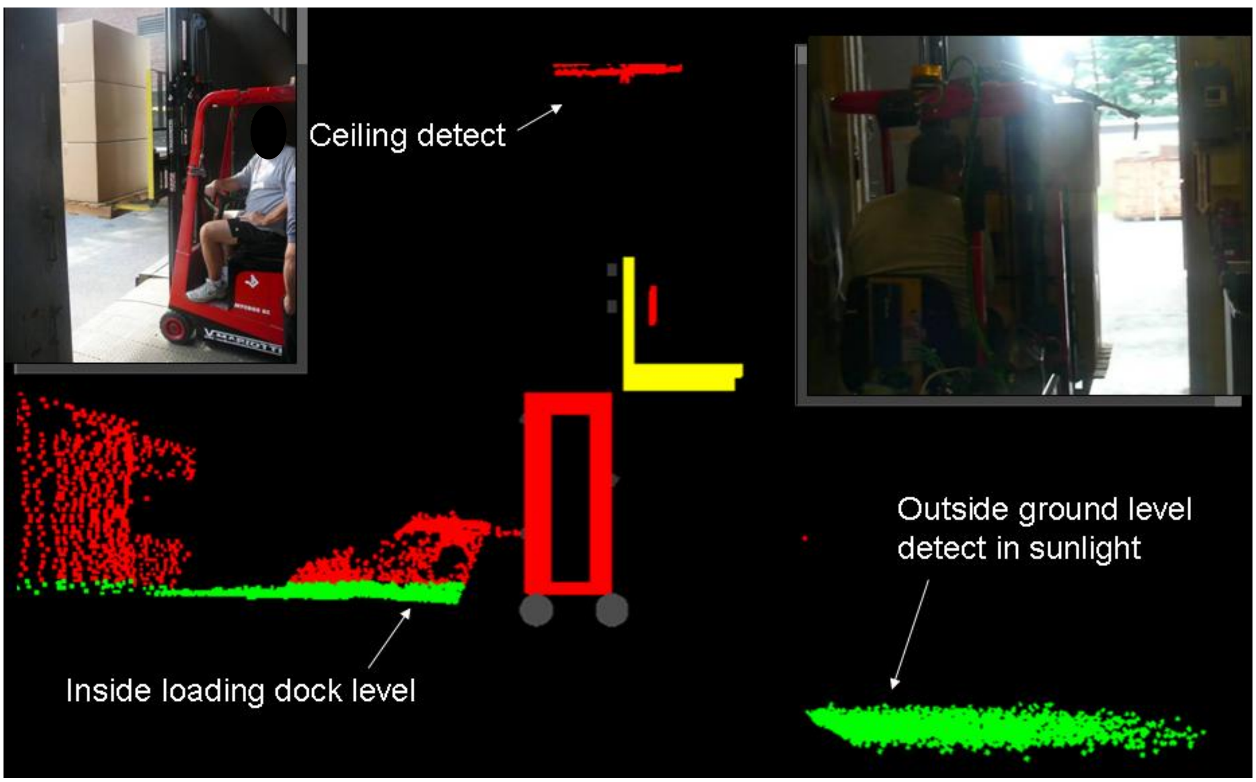

Figure 2 – Data showing detection of both positive and negative obstacles using 3D LIDAR mounted to a forklift while at the edge of a loading dock. The red points are obstacles detected and the green points are detected ground.

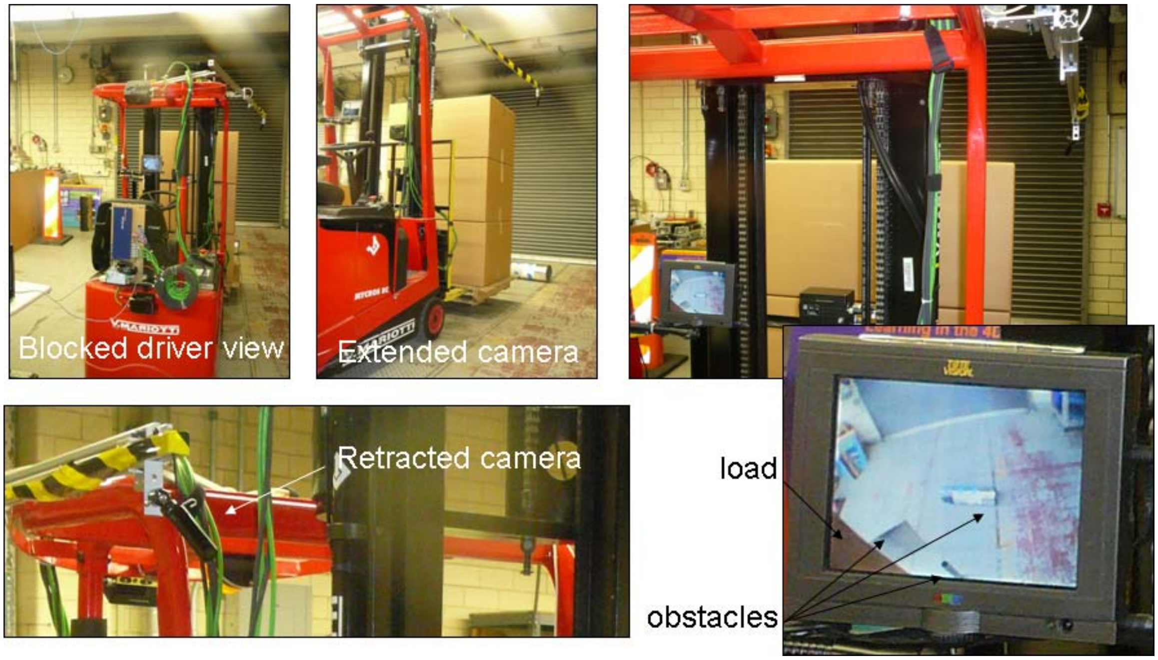

Figure 3 – Color camera mounted on an extendable boom to a forklift to increase driver field of view of B56.5 standard sized obstacles when blocked by loads, bars, and chains. Bottom right shows an onboard monitor displaying camera detected obstacles in front of the forklift load and blocked by the drivers field of view.

5 References

[Chugh], Kevin, "A PC Based Virtual Reality Simulation for Forklift Safety Training," SBIR Phase II, http://www.cdc.gov/od/science/phresearch/pi_abstract2.htm, 2009.

Special session papers presented included the following (in order of their presentation):
[Austin], Mark, "Fork Lift Awareness," Mark Austin, Occupational Safety and Health Administration

[Forsman], Benny "AGV Forklifts - Current and Future Safety Systems,", Danaher Motion, Kollmorgen Corp.

[Ungerbuehler], Richard H. "Where AGV's and Forklifts Roam: Preserving Operational Safety in a Shared Workspace," Sky-Trax Incorporated

[Bostelman], Roger; Shackleford, Will, "Performance Measurements Towards Improved Manufacturing Vehicle Safety," NIST Intelligent Systems Division