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Using 3D camera technology on forklift trucks for detecting pallets

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Abstract

Forklift trucks are indispensable tools for manual pallet handling. Storage heights at high rack storage areas often reach up to 12 meters which in combination with bulky cargo hinder the view of the forklift truck driver.

As part of the joint research project ISI-WALK [1], a 3D-camera-based assistance system is developed at the Institute of Transport and Automation Technology (ITA) to aid the forklift driver especially under limited view conditions. The employed cameras, developed by PMDTechnologies, are integrated into the tips of the forks, thus allowing the detection of pallets and storage racks even if a pallet is already loaded.

INTRODUCTION

The essential function of a fork lift truck is to transport and handle pallets in a storage area. The forklift truck driver has the duty to control the truck and the transported pallet in a safe way so that collisions and damages are avoided. The view of the forklift truck driver is limited during his work by the lift pole, the fork and the roof of the forklift truck. If a pallet is loaded the view is additionally hindered by its load. When the storage rack is not at ground level or near to it the pallet handling becomes more difficult because of the distance between the forklift truck driver and the storage rack.

To support the forklift truck driver during his work, commercial 2D-camera assistance systems are available. These fork-mounted cameras produce video feed from the pallet in front of the truck, which is displayed on a screen inside the driver´s cab. The forklift truck driver, based on his experience has to decide if the position of the fork is correct or whether he needs to adjust it [2]. After loading a pallet on to the truck, the fork-mounted camera is blocked and is no longer any aid for the driver, when for example he has to store the pallet in another storage area.

As part of the joint research project ISI-WALK, funded by the Federal Ministry of Education and Research, a 3D-camera based assistance system is developed at the ITA to aid the forklift driver especially under limited view conditions. The system detects a pallet in front of the forks and calculates its position relative to the forklift truck. By using the calculated information to guide the fork lift driver to the correct position for his truck, the risk of collisions is decreased and the driver is able to focus on the surroundings of his truck [3].

PMD-CAMERA-TECHNOLOGY AND INTEGRATION

Current assistance systems like fork-mounted cameras yield two major disadvantages. Firstly, they cannot calculate three-dimensional information and secondly their functionality is incapacitated when the fork is loaded.

The solution for the first disadvantage is to use 3D-measurment technologies like laser scanner or stereo camera systems, comparable with systems employed for robots and automated guided vehicle (AGV) [4, 5, 6]. Those systems are highly susceptible to mechanical vibrations and therefore not suitable for the challenging conditions onboard a forklift truck. An alternative 3D-mesurment system is the PMD-camera technology. A PMD-camera like the cam board nano (Figure 1 left side) uses a laminar modulated infra red light to measure the distance for each camera-pixel at the same time [7, 11]. The active light source of the camera sends a modulated signal to the scene and the camera-chip compares the reflected and subsequently detected light signal with the current modulation of the light source. The phase shift between both signals is proportional to the distance of the light reflecting surface. Additional to the distance information each pixel of a pmd-chip delivers the intensity and the amplitude information of the detected light. This is the intensity of all infra red light and the amplitude only from the active light source of the camera. Those additional images can be used like normal two-dimensional gray-scale images.

A PMD-camera has no moving and mechanical highly sensitive parts like a laser scanner and doesn’t need as much space as other comparable systems. Thanks to these benefits such cameras are well suited for industrial applications and compact integrated systems.

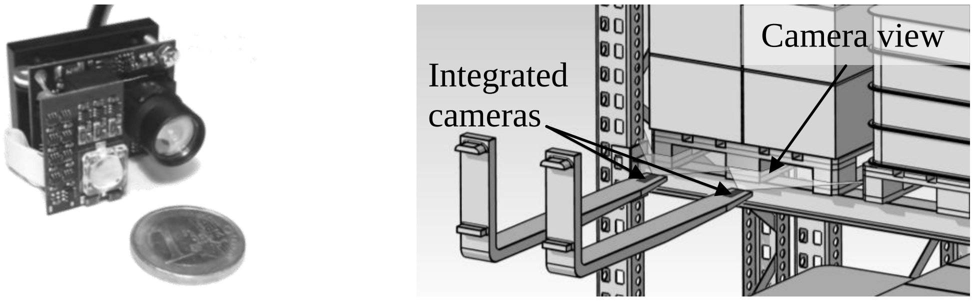

Figure 1: Left: The cam board nano is the currently smallest Time-of-Flight camera with a resolution of 160 x 120 Pixel.
(Image source: PMDTechnologies)
Right: The PMD-cameras will be integrated into the tips of both forks to have an optimal view on the pallet.

Critical in deploying such system even when the fork is loaded, is integrating the camera into a position with free sight at all times. The only positions that fulfill this condition without changing the whole construction of the forklift truck are the tips of the forks as shown at Figure 1 on the right side. A position like the tip of a fork gets highly exposed to the normal daily work of a forklift truck. Therefore, a sensor like a PMD-camera mounted at this position needs to be properly protected against mechanical stresses.

SIMULATION OF THE STORAGE PROCESS

For development and testing of the assistance system and its algorithms it is necessary to create a simulation facility for the storage processes without the risk of damaging the camera systems. Therefore, a test bench with four degrees of freedom was assembled at the ITA. The test bench (shown in Figure 2) allows simulating the relative position between a pallet and the integrated PMD-cameras in horizontal and vertical direction just as the rotational difference and distance. The test bench even allows moving the camera inside the pallet and simulating the loading process of a forklift truck.

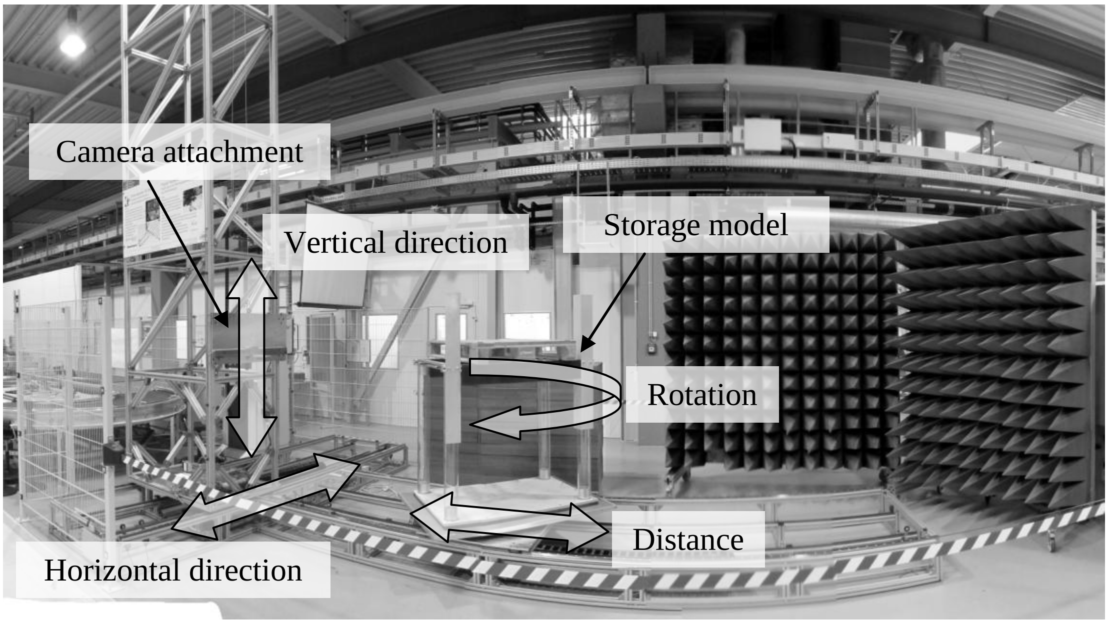

Figure 2: The test bench with the four necessary parameters to simulate the storage process

One segment of typical high rack storages is built out of vertical stakes combined with horizontal brackets, where for example three pallets side by side can be stored. Depending on the position of a pallet inside a rack the images from the 3D-cameras contain different geometric objects. If for example a pallet is stored on the left side of a bracket next to a stake, the resulting image contains parts of the stake as an additional object. The image processing algorithm has to decide whether the detected object is a part of the pallet or the rack. To simulate those different storage situations we use specific models of storage places and storage situations.

RANGE IMAGE PRE-PROCESSING FOR PALLET DETECTION

Reducing image noise

Depending on the camera settings, the images from the PMD-cameras are either more or less noisy. The grade of noise depends mostly on the integration time of the PMD-chip [8, 9]. The longer the integration time is set, the less noisy the images are (see in Figure 3 on the right side). On the other hand even the slightest movement during the integration time span will result to measurement deviations. Additionally, a longer integration time can lead to an overexposure of the camera pixels and furthermore measurement failure of the surrounding area (see in Figure 3 downright). This effect depends mostly on the distance and the reflectivity of the measured surfaces [8]. While proximate surfaces are overexposed because of a longer integration time, more distant surfaces cannot be accurately measured at shorter integration times because of a high amount of noise.

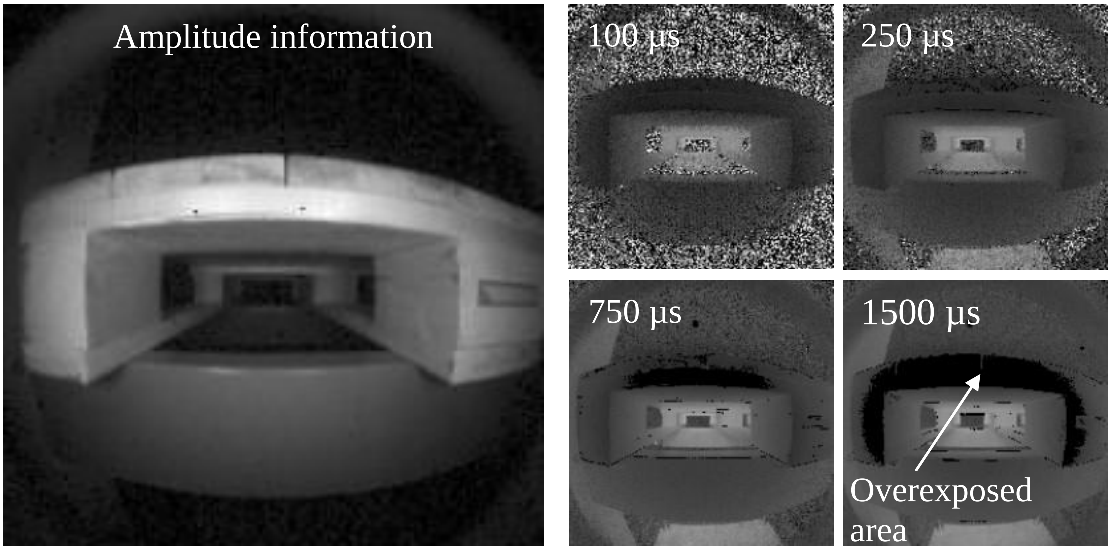

Figure 3: Left: Amplitude information of one single PMD-image with the left front side of a pallet
Right: Distance information of the same scene with different integration times (100 µs, 250 µs, 750 µs and 1500 µs)

Varying the integration time

To solve this occurrence we take multiple images from the same scene with different integration times and combine these images to one single resulting image (Examples are given in Figure 4). The proximate and highly reflecting surfaces are taken from the short integration time image and the more distant and less reflecting surfaces from the image with the longer integration time.

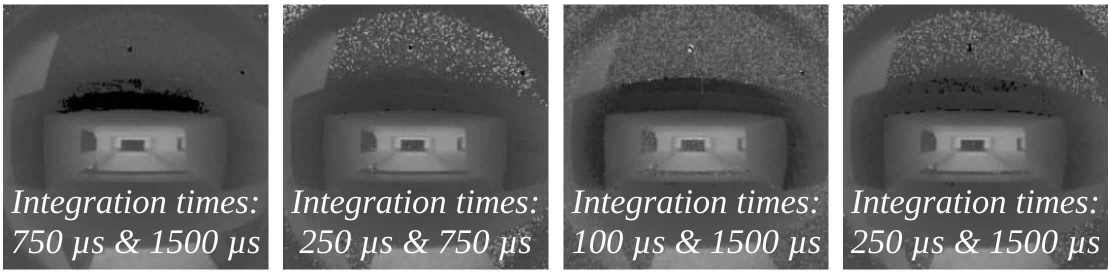

Figure 4: Combinations of PMD-images with two different integration times, the left image still has overexposed areas, the images in the middle indicate too much noise or measurment differences and the image on the right has a minimum of overexposed areas with less noise or measurment differences.

In addition to multiple images with different integration times, image noise can also be reduced by combining images taken with the same integration time or the same combination of different integration times (shown at Figure 5).

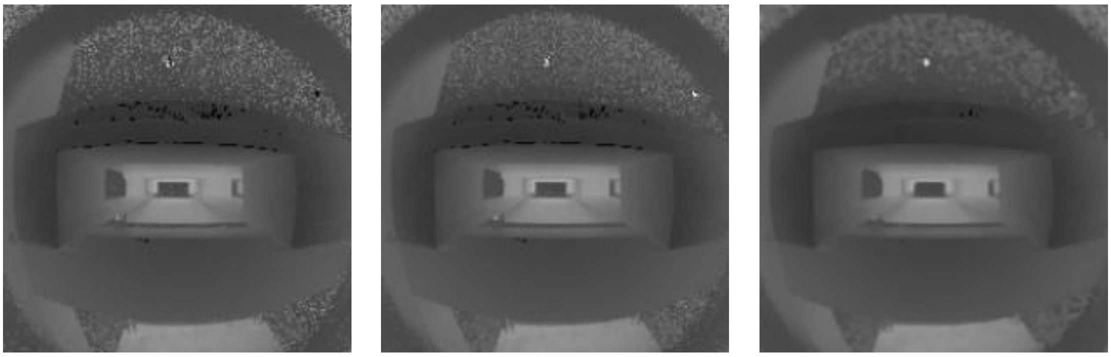

Figure 5: Left and middle: Combination of 2 and 10 images with combined integration times of 250 µs and 1500 µs
Right: Combination of 10 images after applying a median filter with a size of 3x3 Pixel

A noise reduction with algorithms like a median filter or a Gaussian filter is convenient to minimize the residual noise, but in consideration of the preservation of edges inside the image we apply such filter with a size of 9 Pixel.

Figure 5 shows the combination of two and ten images with multiple integration times and the resulting image after applying a median filter. While the noise in the median filtered image is minimised the edges of the pallet are blurred. An alternative algorithm to reduce noise in conventional 2D-images that preserves the edges is a bilateral filter as described in [10]. At range images such filter would perish 3D-surfaces aligned in the direction of the camera axis and is therefore not used on the image data.

CONCLUSIONS

An assistance system based on 3D-camera technology is able to support the forklift truck driver in critical storage situations and under limited view conditions. The cameras used for this system are PMD-cameras. These camera systems are compact and less susceptible to vibrations and mechanical stresses than other comparable 3D measurement technologies. To provide the optimal view on the storage places and pallets the cameras are integrated into the tips of the forks.

For algorithmic development and testing a test bench has been assembled to simulate the storage process of a forklift truck. By using a model of a high rack storage it is possible to simulate different storage places and situations.

To reduce the noise at the images recorded by the PMD-cameras, rather than a single, multiple images with different integration times are processed and combined together into one resulting image information. This is necessary because the surfaces near the camera are overexposed at longer integration times, while the more distant surfaces are noisy at shorter integration times.

At the current project stage the development of the algorithm that calculates the position of the cameras based on the pre-processed and noise reduced range images is in progress. The tasks for future development are translating the camera position to the forklift truck position and presenting this information to the driver. The application test with a complete modified forklift truck and under realistic boundary conditions in an industrial storage and the results of the validation are forthcoming.

REFERENCES

[1] L. Overmeyer, S. Kleinert, *“Stapeln leicht gemacht, 3-D-Kameratechnik unterstützt die Ladungshandhabung und hilft Unfälle zu vermeiden”*, IndustrialVISION 2/2011, S.38-39, Vereinigte Fachverlage, Mainz 2011, ISSN 0936-692x.

[2] L. Overmeyer, S. Kleinert *“Das Lasthandling verbessern”*, f+h, Vereinigte Fachverlage GmbH, Mainz, 2012, Nr. 2, S. 20-22, ISSN 0341-2636

[3] S. Kleinert, L. Overmeyer, „*Intelligente Schnittstellen In Wandlungsfähigen Lieferketten (ISI-WALK), Teilprojekt 3D-Objekterkennung*“, Forschungskatalog Flurförderzeuge 2012, S.13 - 14, Medienzentrum der Helmut-Schmidt-Universität, Hamburg, 2012, ISBN 978-3-86818-037-4

[4] A. Neve, 3*D object detection for driver assistance systems in vehicles*, (Schaker, Aachen, 2009, ISBN 383-2-2846-3X)

[5] D. Lecking, O. Wulf, V. Dierecke et all , *The RTS-STILL Robotic Fork-Lift*, Third EURON/EUnited Robotics Technology Transfer Award, 2006, Palermo, Italy.

[6] G. Ullrich, *Fahrerlose Transportsysteme*, (Vieweg+Teuber, Wiesbaden, 2011, ISBN 978-3-8348-0791-5)

[7] B. Buxbaum, *Optische Laufzeitmessung und CDMA auf Basis der PMD-Technologie mittels phasenvariabler PN-Modulation*, (Schaker Verlag, Aachen, 2002, ISBN 978-3-8265-9805-0)

[8] M. Plaue, *Analysis of the PMD Imaging System*, Interdisciplinary Center for Scientific Computing, Univ. of Heidelberg, 2006

[9] M. Wiedmann, M. Sauer, F. Driewer, et all, *Analysis and characterization of the PMD camera for application in mobile robotics*, International Federation of Automatic Control Seoul, Korea 2008

[10] C. Tomasi, R. Manduchi, *Bilateral Filtering for Gray and Color Images*, IEEE Conference on Computer Vision, Bombay, India, 1998

[11] T. Ringbeck, *Untersuchung opto-elektrischer Phasenregelkreise auf Basis von Photomischdetektoren hinsichtlich deren Anwendungspotential für die Photonik*, ZESS-Forschungsberichte; Bd. 16, (Schaker Verlag, Aachen, 2002 ISBN 3-8265-9789-3)