PAN-Robots
Collaborative project
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Omnidirectional Stereo Camera

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Executive summary

The purpose of this project deliverable is to report the results of the technology development of the PAN-Robots omnidirectional stereo camera sensor for automated guided vehicles (AGVs). This omnidirectional stereo camera sensor is the basis for the PAN-Robots **technical objective 7** [1] of a novel on-board sensing system for AGVs. The development covers actions from optical component design and manufacture to the software development for the 3D perception module. The outcome of these actions is a robust and compact omnidirectional stereo camera that fulfils the specifications for factory environments and for AGV applications. There are no similar sensors available on the market right now.

The PAN-Robots stereo camera sensor will be used to track and detect objects in the AGV's environment, and together with the laser scanners it will form a system which provides 2D safety enhanced by 3D perception. A sketch of this system is shown in Figure 1, where scanning areas and field of view (FOV) of the stereo camera are illustrated. The specific task for the omnidirectional stereo camera system is to detect protruding or hanging obstacles which cannot be detected by the laser scanners. This will enhance the collision avoidance functionality and thus the overall efficiency of the AGVs.

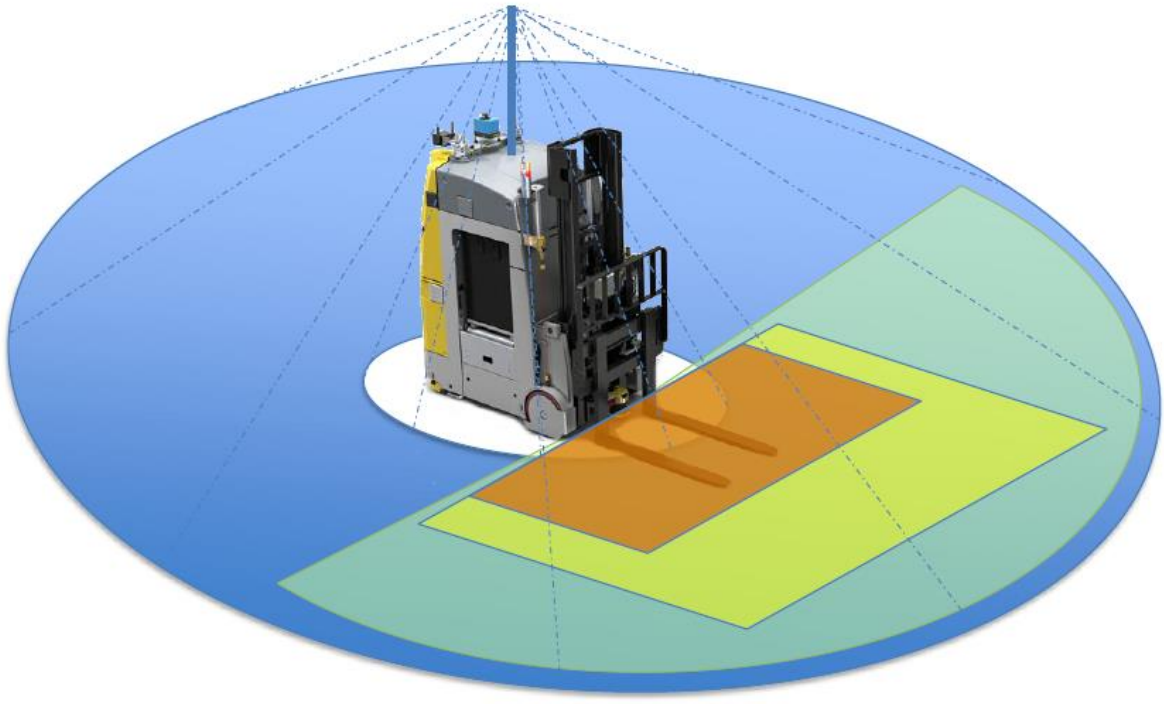

Figure 1: Safety laser scanner field of view (green), safety areas (yellow, orange) and 3D omnidirectional stereo vision field of view (blue)

Two types of low cost omnidirectional lenses have been designed, manufactured and tested within this project. The first design and manufacturing iteration covered the development of an omnidirectional PAN-Robots lens. After that, two further iterations were made to produce the final omnidirectional fisheye lens. These components, together with cameras and software modules, form a rugged and compact stereo camera sensor which offers the interface for mounting the sensor onto an AGV. The lenses and the mounting mechanics have been tested and validated for

AGV applications. Figure 2 shows the PAN-Robots omnidirectional stereo camera sensors mounted on an AGV.

Figure 2: Mounted omnidirectional stereo camera sensor

The software driver performs the image acquisition via a standard interface. A calibration process of the sensor has been developed in order to determine the intrinsic (focal length, radial and tangential distortions, etc.) and extrinsic (i.e. mutual distance) parameters. Using the set of calibration parameters, the distortions from the acquired images are removed and the images are rectified to a canonical configuration. The density of image points before integration is of crucial importance in order to have an accurate image unwrapping and rectification, and consequently, an accurate 3D reconstruction.

The distortion correction and rectification step is followed by stereo-matching, sub-pixel interpolation and finally 3D reconstruction. A sample of a stereo reconstruction is shown in Figure 3. Stereo-matching is performed using a novel stereo reconstruction algorithm capable of high density, high accuracy reconstruction in real-time. A dedicated sub-pixel interpolation algorithm has been developed in order to counteract on the higher error rate associated with the omnidirectional image formation model. The stereo reconstruction is done on a low-power industrial PC.

The omnidirectional stereo camera is able to adapt to different environment conditions. The system has been adjusted, calibrated and fine-tuned using test objects. The overall performance of the sensor has been validated in two field tests sessions and in several laboratory tests.

Based on the results documented in this deliverable, the omnidirectional stereo sensor hardware and software are ready for AGV integration.

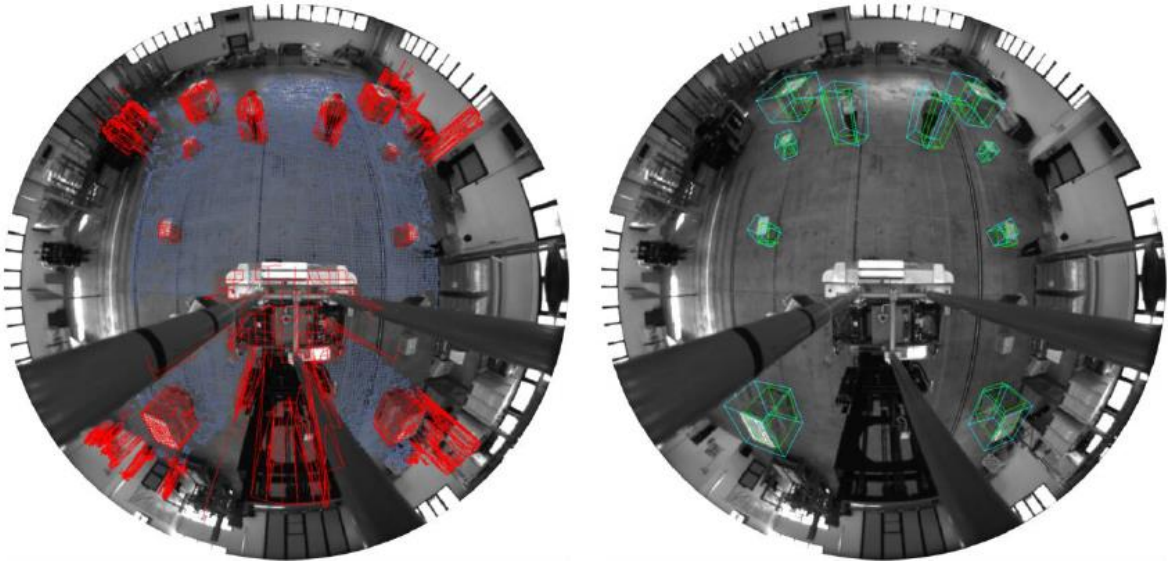

Figure 3: Left: The ground is marked in blue and obstacle boxes are red. Right: the enveloping boxes of the objects. Green boxes represent ground truth objects and cyan boxes objects detected by the system