Autonomous Vision-based Docking of a Mobile Robot with four Omnidirectional Wheels

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Have you ever wondered how mobile robots could recharge at a certain place while no person gets involved? Obviously, accurate robot positioning and reliable obstacle detection are among the priorities too. What hardware and software architectures of the robots are required for successful goal accomplishments in real time? In this summary, you will get acquainted with the concept of multiple sensor data fusion, such as laser scanner and vision sensors to achieve precise docking.

Background

Docking of mobile robots requires precise measurements of the pose pf the robot in relation to the docking platform. Besides, the pose estimation of the robot with the sensors in the indoor environment should be accurate enough for localization and navigation toward the docking platform. However, the sensors are entitled to measurement noise. The sensor data fusion is exploited to decrease the measurement errors and increase the accuracy of the docking.

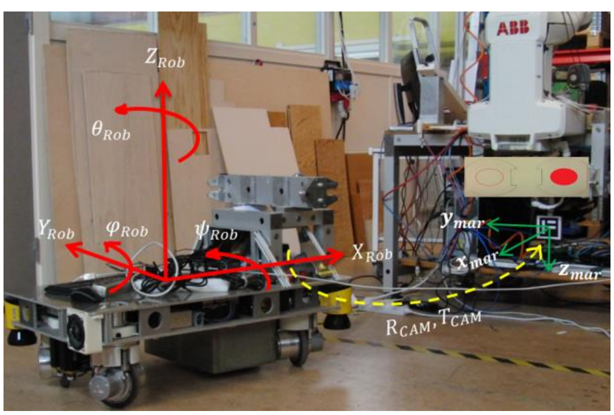

Figure 1 The mobile robot Rob@work 3 and the docking platform under investigation (Alijani, 2016).

Problem Formulation

The end-effectors and the mechanical collinear joints mounted on the mobile robot and the docking platform demand a precision of 2-3 mm for the position and 1-3 degrees for the orientation to accomplish the docking task. Multiple sensor data fusion of laser scanners and vision sensors is investigated to evaluate the pose estimation accuracy of the sensors with respect to the docking platform.

Despite the multiple sensors, the control design, which includes the feedback from the sensor measurements, is crucial to accomplish the docking task with the available sensor measurements. In this thesis, the feasibility of the laser scanners and the vision sensors is investigated to obtain an optimal docking policy which corresponds to the docking trajectory having the shortest average docking time.

Method

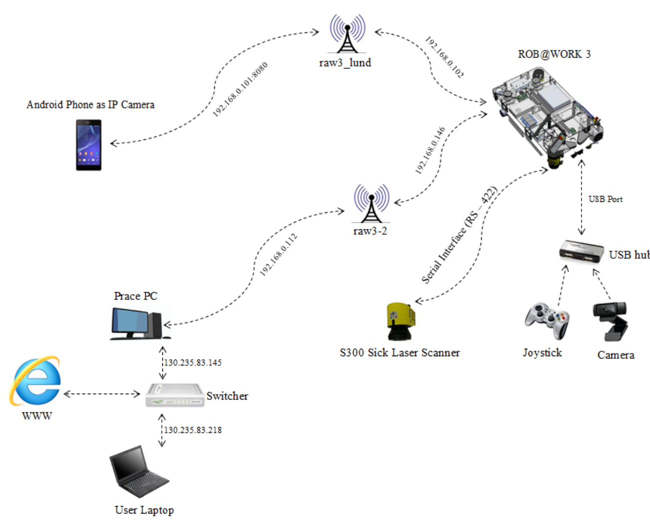

Figure 2 The developed software and hardware architecture for the docking task (Alijani, 2016).

Docking with laser scanners mounted diagonally on the mobile platform is the first approach. Different markers are employed to check the feasibility of the precise docking.

Different approaches to accomplish docking of the mobile robot were investigated. The vision-based feedback control of the Augmented Reality (AR) marker attached to the docking platform is also investigated

with several experiments to accomplish the docking task.
The computer vision is employed to determine the geometry of different coordinate systems, compute camera parameters for calibration, and the pose estimation.
Fiducial markers, including point and planar markers, are used in the vision-based docking for marker detection in the OpenCV library.
Finally, the model free Q-Learning approach is simulated to compare the results of the vision-feedback control in obtaining optimal docking behavior for Rob@work 3. In this approach, the docking area is discretized for the position and orientation and the grid is used to compare to find an optimal action selection policy while the agent which is the mobile robot in this case can obtain the highest possible rewards.

Results

Some of the results from docking of the Rob@work 3 are provided here, but all results are provided in the thesis report (Alijani, 2016).

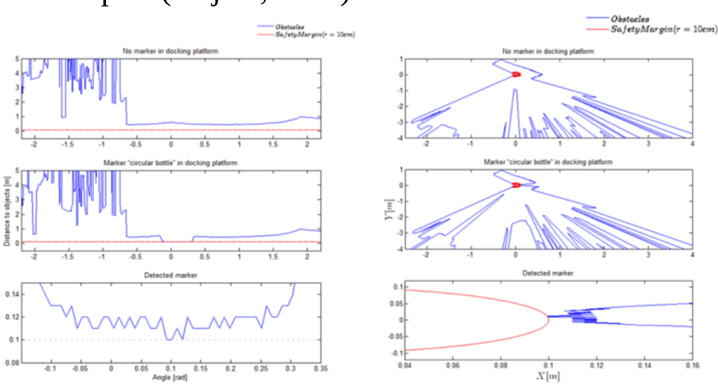

Figure 3 Experiments for the autonomous laser scanner-based docking (Alijani, 2016).

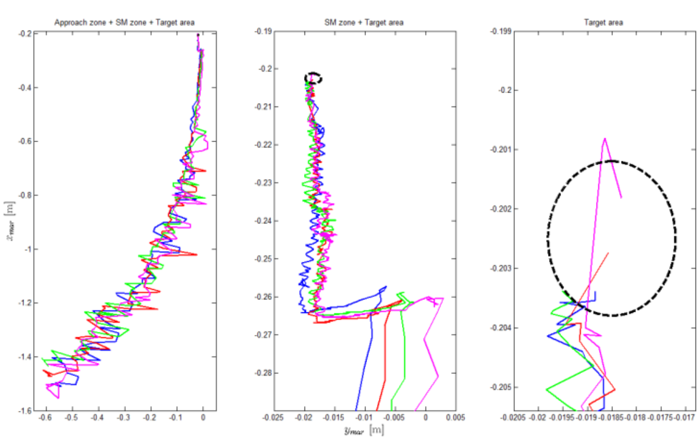

Figure 4 Gain tuning for the designed controller in the autonomous vision-based docking (Alijani, 2016).

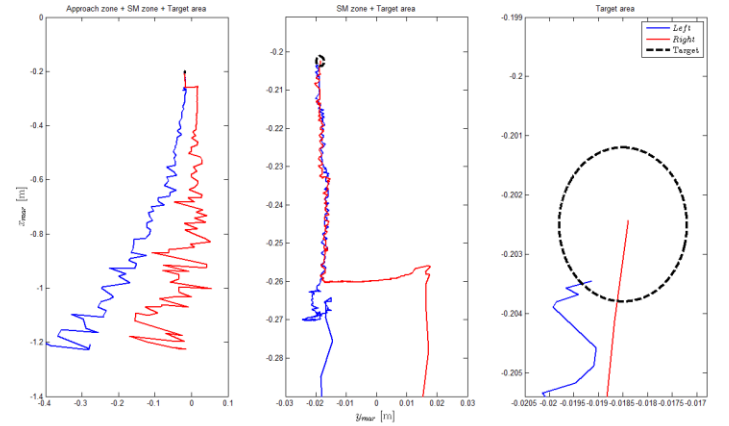

Figure 5 Trajectory of the Rob@work 3 for different initial configurations (Alijani, 2016).

Discussion & Conclusion

Autonomous docking of the mobile robot is quite useful for recharging or attaching to different platforms. The idea of using sensor data fusion improves the docking accuracy.
The docking platform under investigation demands high accuracy of the robot with respect to it. Laser scanners do not exhibit accurate results to accomplish the docking task.
The vision sensors are entitled to errors due to the noisy measurement. Therefore, the computer vision algorithm is employed to calibrate the camera and compute the internal parameters to get undistorted images of the docking platform.
The USB camera has exhibited more robust docking than the IP camera.
The planar AR marker is prioritized over simple point fiducial since it has the capability of 3D Pose estimation $(x_{mar}, y_{mar}, \theta_{mar})$ and higher detectability in environments with several disturbances.
Sensor data fusion leads to higher accuracy in the docking task.

Reference

Alijani, F. (2016). *Autonomous Vision-based Docking of a Mobile Robot with four Omnidirection Wheels.* ISRN LUTFD2/TFRT—6018—SE. Lund: Department of Automatic Control, Lund University.