Being safe around collaborative and versatile robots in shared spaces

Case story:

Domain:

From award project: Mobile Item Picking Robot (MIPR)

Project beneficiaries: Smart Robotics

From open call nr: 1

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1 Overview

The mobile item picking robot (MIPR) project is focused on the integration of a cobot arm on an autonomously guided vehicle (AGV) to perform pick and place activities in warehouse environments with static shelves. Smart Robotics BV is a system integrator working with various end-users in the domains of manufacturing and logistics. The developments in MIPR are based on the integration of two existing technologies within and outside Smart Robotics:

- Stationary item picker (a Smart Robotics product), consisting of UR cobot with 3d vision and deep learning system, picking products from totes (currently supplied with conveyors).
- AGV, an externally delivered product, equipped with a lift to bring the UR to higher shelves.

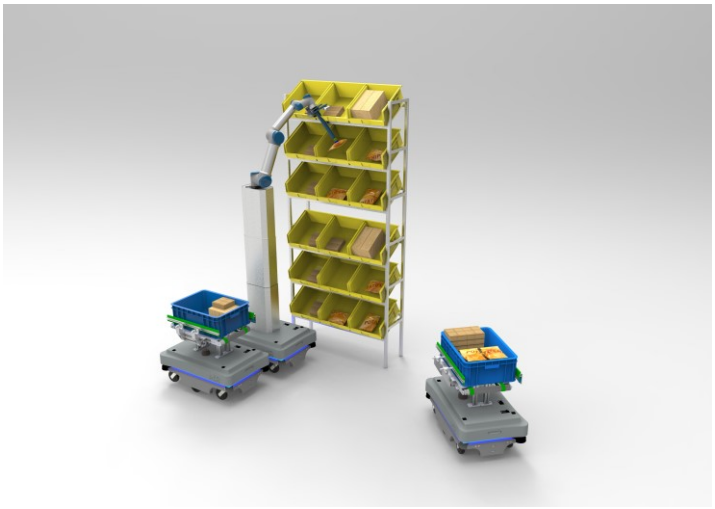


Figure 1: MIPR use-case from Smart Robotics

There are numerous safety considerations when combining two systems (AGV and cobot arm). Both rely on their own safety control system, covered through dedicated norms. Typically, the safety of the AGV is ensured through distance sensors (either through a safety-rated monitored stop or speed and separation monitoring) and the cobot is safeguarded through power and force limiting. MIPR originally foresaw combined robot and AGV motions during normal operation in a shared workspace with humans.

2 Safety Challenges

Safety for cobots and AGVs is well understood and is based on the available international standards (e.g. ISO 10218, ISO/TS 15066, ISO 12100, ISO 13857, ISO 3691-4, and ISO 13849). These standards, however, do not specifically cover an integrated system with a robot arm on top of an AGV and the following issues were identified by the MIPR project:

- The safety of a static robot is highly dependent on the environment (contact with sharp objects is not allowed, clamping of a person with objects such as tables, shelves, etc. is not allowed), but in our mobile item picker we have only limited control over this environment and are not always aware of relevant changes.

- The operation manual of common cobots suggest that the support of the robot should be 10x the max load on the robot end effector. This requirement results in an AGV that is potentially too large to efficiently move through the picking lanes foreseen for the MIPR application.
- Floor markings are typically suggested for marking the operational space of a cobot. This is not possible with a cobot on a mobile platform and a more dynamic solution is needed.
- The safety of the AGV is achieved through maintaining a separation distance to humans, sensed with various distance-measurement sensors. However, in the mobile item picker, the footprint of the complete robot system can change dynamically due to the movement of the robot arm outside of the footprint of the AGV.
- In situations where the maximum cobot velocity is limited (e.g. when operating with power and force limiting), combined velocities due to overlapping AGV and cobot motions need to be considered to avoid collision forces and pressures above the biomechanical thresholds from the ISO/TS 15066.

In addition to gaps identified in the standards, this integration of a cobot and AGV, each with their own separate safety system is a big integration challenge. The cobot is designed and meant to physically interact with its environment, but the AGV is typically designed to keep a certain safety distance from detected obstacles. To achieve efficient operation of the item picker whereby cobot and AGV are both moving at the same time, a conflicting situation between both safety systems could result.

3 Solution

Smart Robotics carried out an exemplary risk analysis, and concluded in the end that it is simpler and more effective for the overall system to separate cobot and AGV motion after all. Therefore the movements of AGV and cobot are decoupled: when AGV is moving, the cobot (including gripper) has to be inside the footprint of the AGV.

The concept chosen is as follows: AGV

- The AGV cannot move while the cobot is moving.
- When the AGV is moving, the cobot is in a parked position, holding no items.

To ensure this we connect safety signals from the cobot to the AGV safety system:

- cobot is not moving
- cobot is within safety plane (in parked position).

To ensure that the cobot will not operate when AGV is moving, a safety signal output from the AGV is connected to safety system of the cobot.

The picker unit works in a corridor. When an operator enters the corridor, the AGV is not allowed to move or only at a reduced speed. The presence of a human will be detected by AGV's lidar sensor. With these measurements, and using the the safety zone calculation from the ISO/TS 15066 and the separation distances of the DIN EN 1525 of 0.5 m to both sides (2.1 m high), the system is able to comply with safety requirements.

The protocols for ensuring that the limiting the energy during a collision were executed with the mobile manipulator. The goal of the measurements was to determine the forces and pressures that occur when the cobot (a UR5) with and without a gripper hits an operator. The conditions of the experiments were varied as follows:

1. Varying configurations of the UR5 arm, that is, various impact locations and varying robot arm movements
2. Varying surfaces at impact, this was achieved by using two separate grippers and certain surfaces of the cobot itself
3. Varying impact velocities
4. Varying payloads by adding extra mass to mimic items that will be held by the cobot

The following generalizations can be made from the measurements:

- The impact pressure was measured for a specific set of tests. For the other cases, the contact area was large enough that the force limit was exceeded before the pressure threshold. Hence, the pressure value was not relevant for all the measurements.
- Increasing the payload (mass) increases the impact force.
- Measuring the Joint Cap 4 of the UR5 robot arm resulted in a greater impact force than the two grippers using a similar configuration and impact velocity. The limiting factor from a safety perspective is therefore the UR5 robot arm. Furthermore, only Joint Cap 4 was tested during the experiments. There may be spots on the UR5 that will result in even larger impact forces and pressures. The reason that other spots were not tested was due to time constraints.
- There are configurations of the UR5 without a payload that resulted in higher measured impact forces than other configurations with a payload of 5 kg. Therefore, both configuration of the robot during impact as well as the payload have a significant on the impact force.
- The precise reason why some configurations are more compliant than others is still unclear.

4 Conclusion

The MIPR project looked at the safety related aspects for a mobile manipulator working in close proximity to humans in a warehouse environment. The risk analysis highlighted some of the typical issues system integrators working with mobile manipulators face, especially in cases where two separate products from different vendors are integrated into a single system.

Additionally, the protocol “Test robot arm for collision with fixed object” was used to validate whether the interaction energy is limited in the case of a collision with the robot arm.

The complete deliverable can be downloaded here.