"Safe navigation and human-robot interaction in assistant robotic applications"

Candidate: Pangcheng David Cen Cheng (XXXV Cycle)

Supervisor: Prof. Marina Indri

Summary

In recent years, robotic systems have been employed widely in many fields. In an industrial context, robots are generally used to automatize manufacturing processes in hazardous environments for human beings or to relieve humans from repetitive and rough tasks. Nowadays, where the presence of the human operator is becoming more relevant, the production focus is aimed to have robotic systems supporting human activities. In this context, the aim of this PhD thesis is to study and illustrate different approaches that enable safe human-robot interaction in an industrial context.

The main research focus is the improvement of the performance of existing robotic systems in the industry, such as mobile robots, manipulators and mobile manipulators, to enhance their perception of their surroundings as well as the presence of human operators in the same working space. In order to do so, the research work proposes feasible methodologies for mobile agents and manipulators to work safely in the presence of humans, exploiting open-source frameworks along with affordable sensory systems for sensor data fusion. In particular, among the various research topics that were investigated and developed are:

• Safe path planning algorithms for autonomous mobile robots with human-obstacle avoidance

• A sensor data fusion algorithm to improve the robot's awareness of the environment and human detection

• Alternative frameworks to enable safe interaction between human and robots

For what concerns the robot's navigation algorithms, most of the path planners generate an optimal solution in terms of distance or time, but they do not consider the human safety. The developed path planning algorithms provide an additional safety layer within the robot's navigation system to safely avoid humans in an environment where humans and robots coexist. Different planning levels were designed, for instance, a supervisory planner for computing a deterministic reference path and a local planner able to deal with human obstacles. The algorithms have been developed employing MATLAB and open-source frameworks such as ROS (Robot Operating System). MATLAB was mainly used to compute the waypoints of the reference path while ROS was exploited for managing the data coming from the sensors and commanding the mobile robot.

The robot's navigation system can be also improved by upgrading the perception equipment to detect specific obstacles, especially humans moving too close to the robot in motion. An example of this is combining the data coming from a camera, a laser range finder and an object recognition system to identify an obstacle and have the corresponding distance

associated to that obstacle, so the mobile robot can execute ahead the path replanning. The sensor calibration has been performed using the MATLAB tools, while the data coming from the visual sensor is processed using the YOLO (You Only Look Once) object detection system, so the robot's perception system is able to differentiate between general obstacles and humans.

In the case that the robot has the capability to autonomously perform low-level tasks, such as path planning and sensing the environment, it is possible to build an organized framework to provide support and assistance to human operators, in which the robot can continuously learn about the human actions and execute high-level commands. Such a framework takes into account state-of-the-art solutions for human perception as well as object manipulation considering the object affordance.