Trajectory planning of collaborative robots for industrial tasks in dynamic scenarios

In the most **innovative automatic machines**, the products to be handled are transported from one station to the next not through traditional transport systems, such as conveyor belts or carousels, but by **special robots**. The robots pick up the products from one station, handle them properly, deliver them to the next station, where they are taken over by another robot. The products are manipulated by a single robot at a time and the designed trajectories are, for the most part, "rest-to-rest". The robots are, in most cases, all the same, thus achieving extreme **modularity in the machine design**, with their intrinsic versatility allowing them to effectively perform the distinct operations that are needed throughout the machine. The same sequence of robots, conveniently reprogrammed, can handle several formats of the same product or even different products, without requiring any major mechanical replacement, except, possibly, for the end-effector or gripper grasping the product. The high flexibility provided by the robots comes at the price of the increasing **complexity of the robot programming**. Nowadays, each trajectory of each robot is programmed by 'hand' by the machine designer. Usually on a trial-and-error basis, the designer establishes position set-points that allows the robot to avoid interference with the surrounding parts of the machines and builds a trajectory keeping into account the desired starting and end poses, as well as, in an approximated way, the dynamical constraints imposed by the cycle time, the available hardware (speed and torque limits at the joints) and the product handling. The typical example for this application is the **manipulation of vials or vessels** containing liquids. In order not to dirt the vessel walls, the liquid **sloshing** must be limited, which sets a limit on the vessel accelerations. The design of such trajectories is a time-consuming process that rarely produces a truly optimized design. Considering that the robots to be programmed may be tens and the process must be repeated ex-novo for each distinct format, the entire process is inefficient, and the results are suboptimal.

This project aims to develop a **software tool** that can **automatically design the most suitable trajectories for the sequence of robots**, by considering the kinematic and dynamic constraints set by the handling tasks that need to be performed, the interference with the environment and between the robots, and optimizing performances. Though the operation environment is structured, the scene is partially dynamic, since adjacent robots share the same space, and their motion is not a-priori known. In particular the tool will:

- plan a collision-free maximum-performance trajectory considering the hardware limits set by the robot capabilities and the static obstacles inside the scene,
- incorporate refined trajectory performance optimizers based on specific product-handling tasks (e.g. limitation of the sloshing phenomenon);
- make use of planning features that can guarantee inter-robot-collision avoidance when adjacent robots share the same operational space;
- be complemented by a dynamic re-planner for real-time applications, that can replan the robot motion based on the information coming from the sensors installed in the machine.