Avoidance of the singularities of a redundant arm through visual servoing

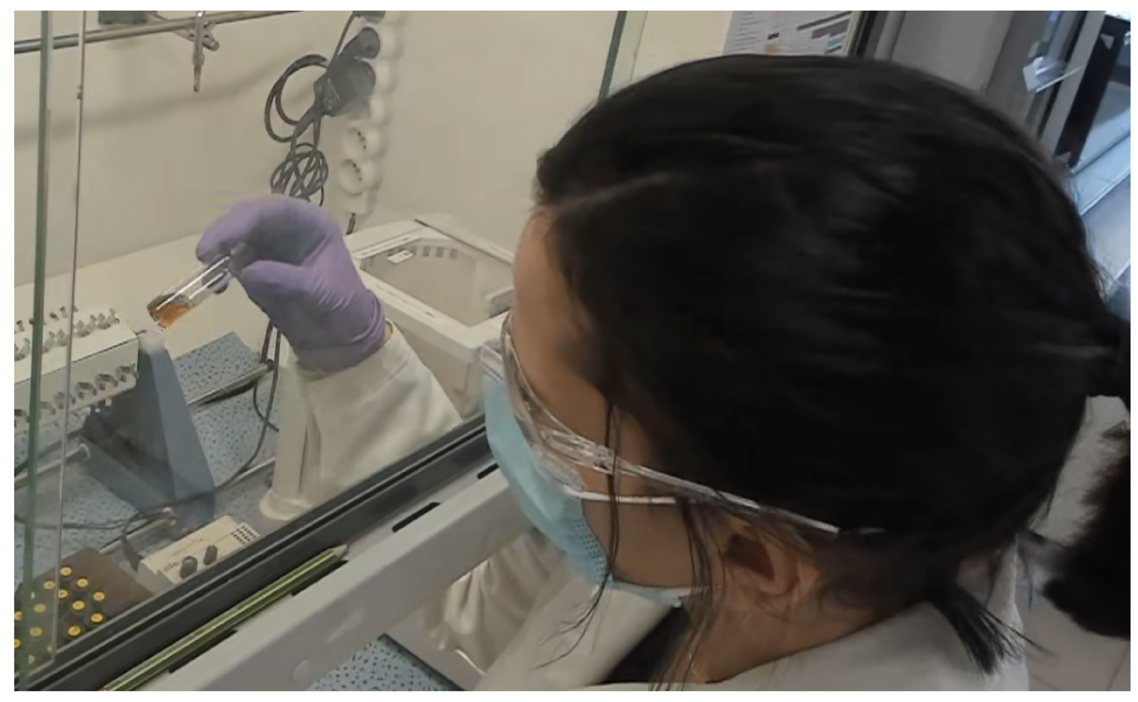
Landais Erwann, Padois Vincent, Rezzoug Nasser

Auctus Inria, IMS, F-33405 Talence, France
Contact : erwann.landais@inria.fr

1 Context

In order to be efficient, a teleoperated system applied to a fragile product handling and classification task must have a sufficiently intuitive control to correctly express the user's expertise on this task. One approach is to directly follow the positions and orientations commanded by an expert via an ungrounded portable device.

However, using this type of teleoperated system is risky as it leads to ignore the kinematic differences between a user's arm and a robotic arm. A movement that can be performed by a user may well be impossible for a robotic arm, leading to an unrealistic or even dangerous control. It may also be difficult to warn the user of those singularities so that he performs the necessary corrections.



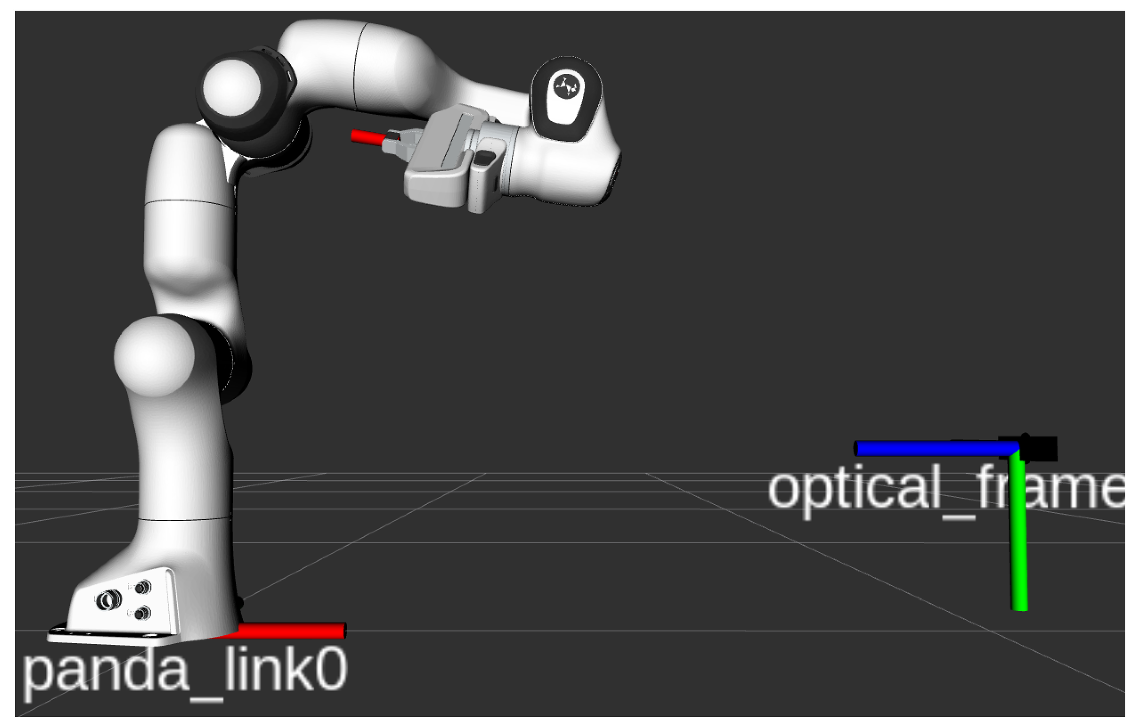


Fig. 1 (up) and 2 (down) : Illustration of an expert handling task, simulation of the robotized part of a teleoperation device

2 Proposed method

Maximization of freedom by deceiving the visual feedback

This problem of singularity of a robotic arm can be reduced by adding additional degrees of freedom to realize the desired commands. Here, an additional degree of freedom is obtained by restricting the user's vision of the manipulated object to the visual feedback of a monocular camera. End effector movement along this axis is hidden by restricting the user's view to a resized camera view. Ungrounded portable device movement along this axis only controls the size of the visual window around the vial (*window feedback size*, in m).

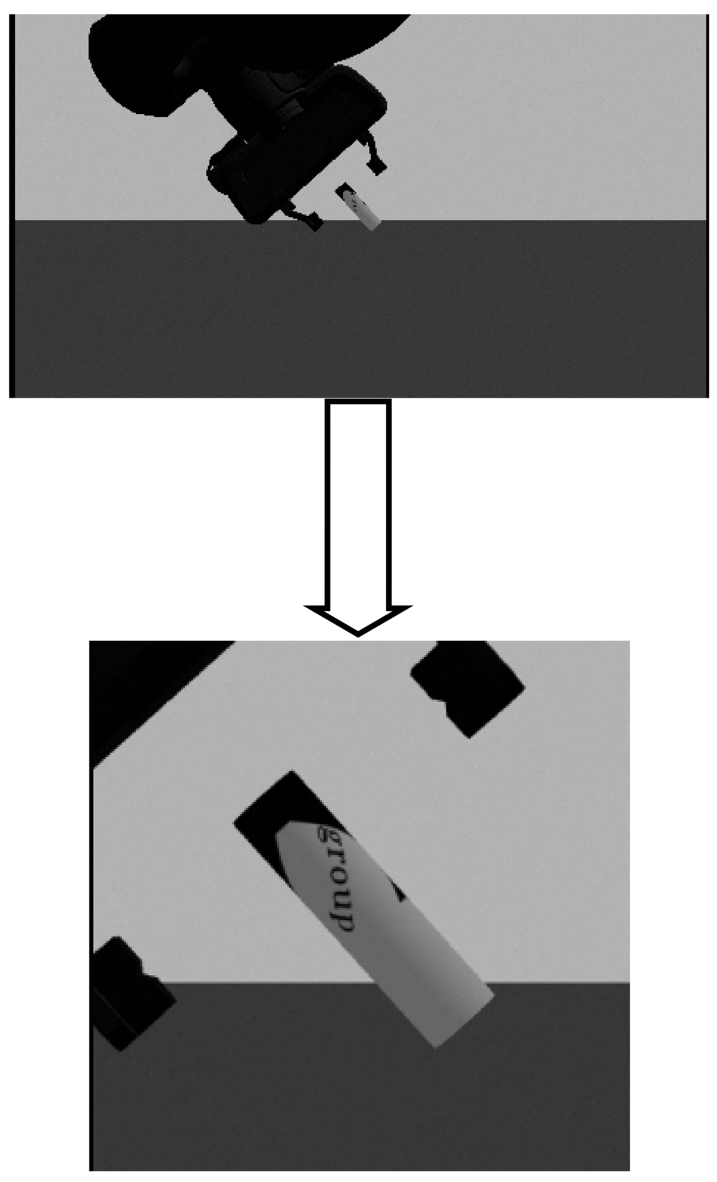


Fig. 3 : Example of a resized visual feedback

Control through Quadratic Programming

Depending on the desired pose (*des*) and the current position (*cur*) of the end effector, the window feedback size, the limits on the depth axis (Z_{limits}) and a pose (*com*) to be reached by the robot are deduced. In order to reach this pose, to respect different constraints (presence of the end effector in the camera's field of view) and to optimize the placement along the depth axis, the command sent to the robot is obtained by Quadratic Programming (QP). A regularization task is used to avoid singularities.

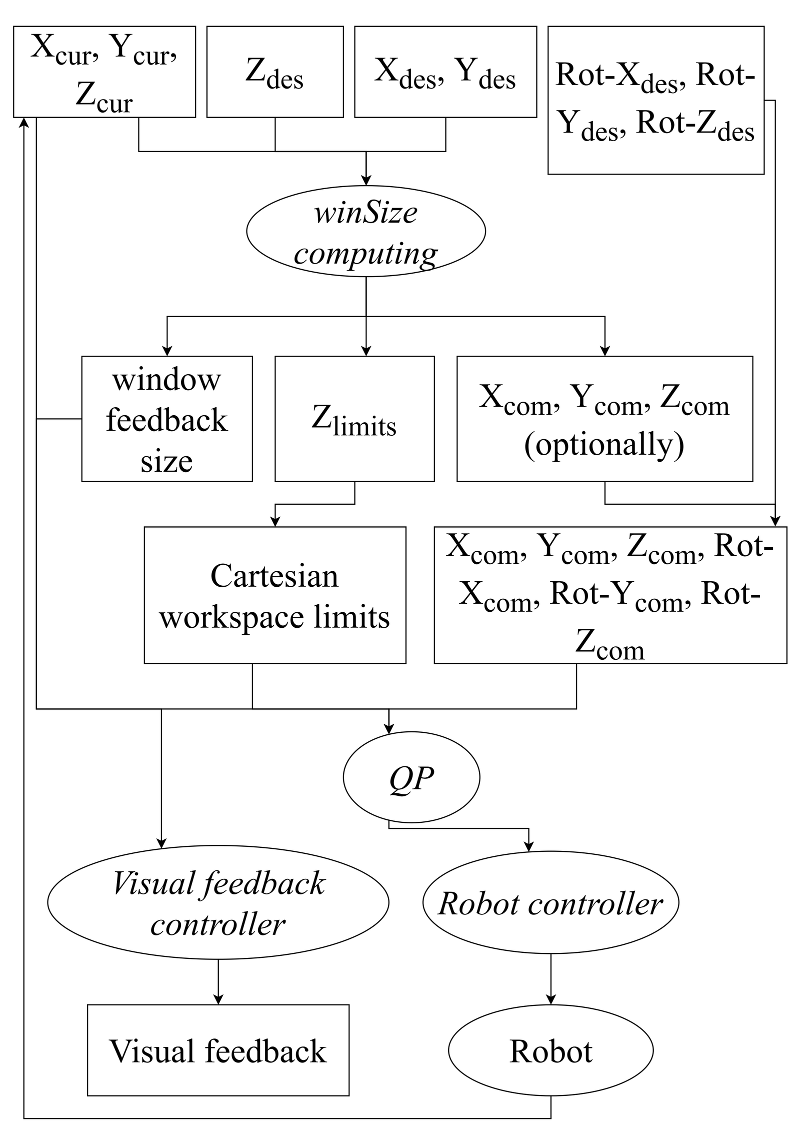


Fig. 4 : High level diagram summarizing the robot and visual feedback control approaches

3 Preliminary tests

Preliminary tests were performed on a set of simulated movements characteristic of the expert task. A comparison is made between a control via QP at a fixed camera depth and at a free depth.

The initial findings are:

- The displacement along the depth axis seems well compensated by the camera for an initial resolution of 2560x1440.
- Some singularities are dodged well, but the results are still too random to be applied to a real case.

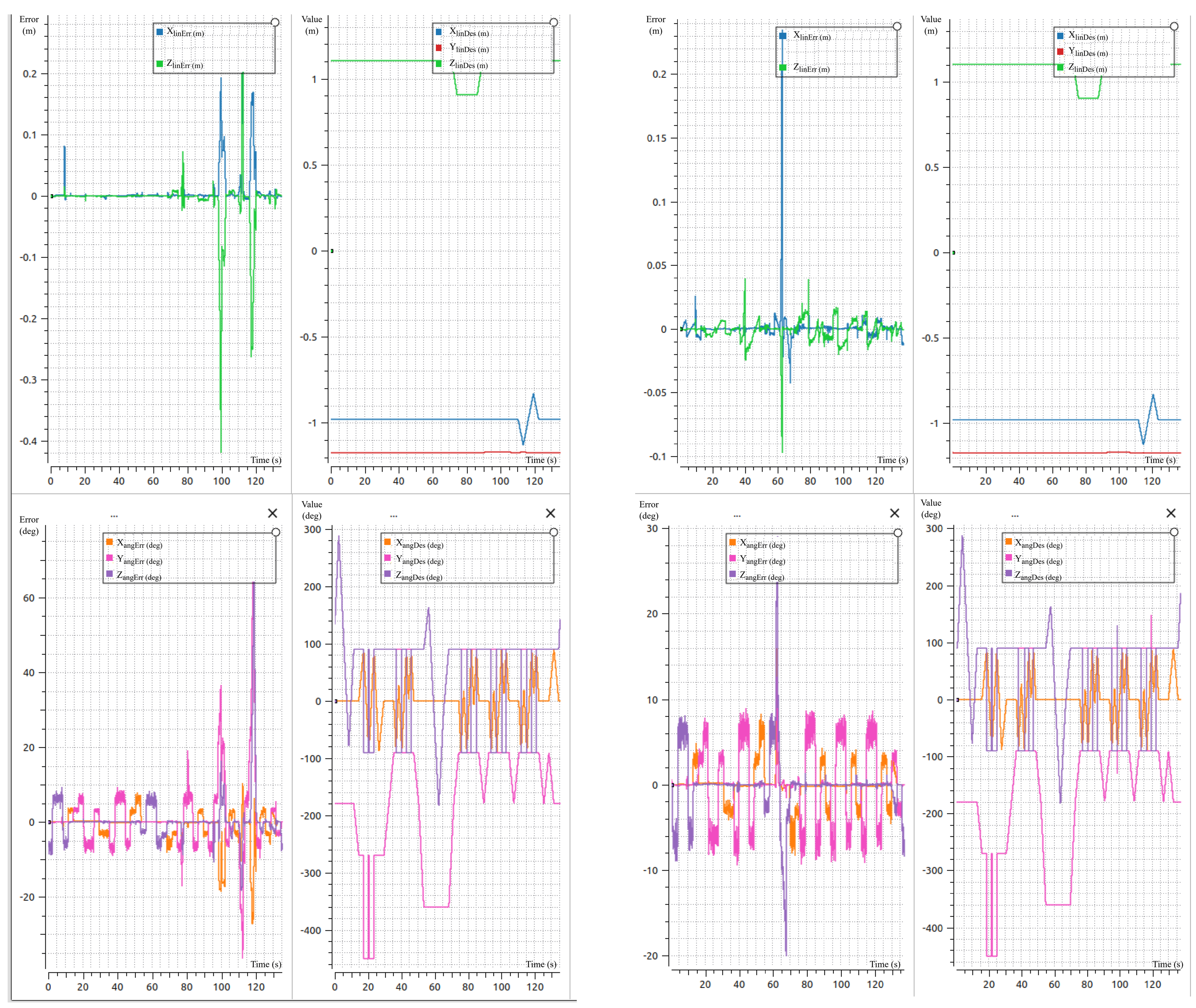


Fig. 5 (left) and 6 (right) : Results for a check via QP at a fixed camera depth and at a free depth.
Left part : difference (in meters and degrees) between the desired pose and the pose reached by the robot, on each axis.
Right part : desired pose (in m and degree), expressed in relation to the global reference frame.

4 Future works

Future work will be divided into two tracks:

- Improving the design of the QP controller to avoid singularities during task execution. One track is to divide the realization of the main task according to the joints of the robot.
- Limit the user's control to only the speed and direction of a set of paths corresponding to the essential movements to perform the task.